出國報告（出國類別：實習）

研習「美國空氣品質預報及模擬」

服務機關：行政院環境保護署

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派赴國家：美國

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摘要

美國區域性氣象及空氣品質預報，主要由 NOAA 進行，涉及團隊包括大氣資源實驗室(NOAA Reseach/ARL)、國家環境預測中心(NOAA/NCEP)等，分別負責模式之研發改良、模式測試驗證與預報系統維護執行等，層層分工（參圖 1）。NOAA/NCEP/EMC 原來主要業務爲氣象預報模式測試與驗證，數年前才開始接手空氣品質預報模式業務，故與其他單位仍有業務重疊之處，仍待統整，此點與國內相似。國內現行預報作業，分由氣象局執行氣象預報、環保署執行空氣品質預報，環保署限於人力不足，在空氣品質預報發展上，有相當限制，未來環資部下如能設立專職團隊，統籌辦理氣象預報與空氣品質預報，將有助於空氣品質預報技術之精進與改良。空氣品質預報人員，需具備專精之氣象與大氣模式能力，NOAA 有許多其他國家之 1 年交換學者共同工作，建議我國派員進行短期或發展長期之人員培訓，與美國持續辦理技術交流，汲取先進技術經驗，以利我國空氣品質預報技術之長程發展。

目錄

壹、目的及背景說明

我國環保署除運轉空氣品質自動監測網，並全年無休提供民眾空氣品質預報服務，爲增進本署空氣品質預報作業，需借鏡國外作法，爰派員赴美國海洋大氣總署(NOAA)研習空氣品質預報模擬運作，以供業務推動參考。

美國海洋大氣總署在海洋與大氣之研究歷史,可追溯自 1807 年對海岸之探勘，迄今廣達太陽表面、大氣、海底深層，均屬於其研究範圍，從每日天氣預報、暴風雨預警、影響漁場的氣候監測、海岸復育至遠洋商務，均爲其研究服務範圍，在科學、環境議題領域上，均具備國際領導地位。

人類觀察天氣已有數千年，但是對複雜的大氣現象一直無法深入了解，近幾十年來，科學家研發尖端儀器、觀測衛星，每天研究結果，才逐步對大氣現象的形成過程，有了明朗的了解。美國海洋大氣總署研究單位在氣象與空氣品質上，推展高空與低空環境之基礎研究、應用研究，研究結果據以規劃國內與國際之環境計畫、國際協議。近幾年，應用衛星觀測、杜朴勒天氣雷達等觀測資訊，以及改進數值模式，已大幅增進天氣預測之效能，即時掌握惡劣天氣之發生及發布預警。此外，美國海洋大氣總署研究單位並觀察及研究大氣的化學和物理變化過程，檢視污染物的影響，監測及預測這些污染物在大氣環境之變化。

鑑於美國海洋大氣總署(NOAA)在海洋、大氣、空氣品質監測預報及擴散模擬上，已有長程之發展，具備先進技術與經驗，本次研習目的在觀摩其大氣資源研究室(NOAA/OAR/ARL)，學習其模式運作制度、擴散模式模擬、氣象及污染源資料庫之投入整合、各單位之配合等，並進一步走訪相關單位，觀摩近海水域監測應用，期能藉由此研習，汲取美國空氣品質預報模擬、水質監測之運作經驗，以利環境監測業務之推展。

貳、研習過程

本次研習美國海洋大氣總署(NOAA)空氣品質預報模擬運作，主要瞭解美國空氣品質預報擴散模擬、氣象與污染源資料之投入整合、單位間之合作等作法，以供業務推動參考。行程與內容摘要說明如下：

一、美國對機關之安全防護相當嚴格，進入機關需數日前申請、審核。

第一天中午抵達後，先與接待人員會面，瞭解前往 NOAA 大氣資源研究室（NOAA's ARL）、國家環境預測中心（NOAA's NECP）路線、交通，然後了解機關進入程序與詳細日程。美國對機關之安全防護相當嚴格，除了數日前即需由內部職員填報訪客資料以申請核准，進入機關人員均需通過金屬感應門、隨身包裹則需經 X 光掃描及感應，並有約 3 名安全人員警戒。（ARL 與 NCEP 分別位於華盛頓特區的北方與南方，合作關聯如圖 1，建物外觀如圖 2 至 3）

二、空氣品質預報需整合諸多專長人力，始能竟其功。

美國國家空氣品質預報，由許多單位共同合作，NOAA's OST 負責協調整合，ARL 負責污染排放資料處理、模式研發，ESRL 負責化學資料之模擬，NESDIS 負責衛星資料處理，NCEP/NCO 負責操作管理，NCEP/EMC 負責，US EPA 負前置測試、驗證責 CMAQ 空氣品質模式之發展研究、空氣污染評估及觀測資料提供，地方環保單位負責當地空氣評估、空污事件之警戒，NASA 則協助衛星之研發、衛星觀測資料提供等。

第二天見習 NOAA/OAR/ARL 擴散模式修正結果檢討會議，會後並逐一向小組成員請益，以深入了解工作的內涵與問題。ARL 主要工作爲編修空氣品質預報模式，提供 NCEP 進行測試，其資料來源除了氣象資訊外，尚需美國環保署提供污染排放分布、主要城市即時空氣品質監測結果等。

小組成員工作包括氣象資料處理(成爲模式輸入格式)、排放源組態修正、地形資料修正、模擬結果比對與擴散模式修正等。ARL 原本隸屬於美國環保署，約兩年前改爲隸屬於 NOAA。（接觸人員如圖 4 至 5、資料如附錄一）

三、模式需不斷測試、驗證、修正參數，使預測結果更準確。

第三天赴 NOAA/NWS/NCEP 了解空氣品質擴散模式測試、問題回饋、預報結果運用等。NCEP/EMC 主要進行 ARL 模式測試與驗證，常規預報則由 NCEP/NCO 執行，並將預測結果數據上網，供美國環保署、地方環環保單位參考使用。NCEP/EMC 的主要工作是呼應操作面需求，進行程式之維護與改良，包括氣象預測、海洋預測、氣候預測，現階段任務包括統合中尺度模式系統、統合全球預測模式、資料同化、每日空氣品質預報、颶風預測、路地表面模擬等，並針對計畫要項提出建議。

美國每個州有自己的預報局，針對地區特性修正 NCO 提供的預報結果，或自行發展預報模式。未來 NOAA 模式發展，將開始著手生態系統模擬。（接觸人員如圖 6 至 7、資料如附錄二至三）

四、模式之運作驗證，需結合環保署、NOAA、NASA 等相關大氣監測資料。

第四天拜訪美國太空總署（NASA），因未於行前(約需 1 個月)提出申請，故僅能參觀外部設施及展示場，及與 NASA 人員作口頭洽詢，NASA 在空氣品質預報上之貢獻，主要爲提供衛星遙測資料，供長程傳輸預報及模擬使用。

我國環保署於 2009 年 1 月成立東沙空氣品質背景監測站，同年 9 月順利推動我國東沙背景測站加入 NASA 氣膠監測網，將東沙背景測站提升爲國際級測站，與全球同步監測長程傳輸污染物變化情形，目前持續強化該站之監測設備，將增設太陽輻射儀，加入 NASA 輻射通量監測網；並將增加懸浮微粒監測設施，監測大陸沙塵及東南亞生質燃燒事件對我國的影

響，長期進行南海環境品質監測，掌握跨境污染物之傳輸情形。

爲瞭解空氣污染長程傳輸對我國及全球環境生態之影響，未來我國環保署將積極參與國際環境監測合作，包括美國環保署（USEPA）、太空總署（NASA）、海洋大氣總署（NOAA）等，以及持續與鄰近國家進行監測資料交換或聯合觀測等環保合作，藉由全球性環境監測活動，促進我國環境監測技術與國際接軌。

五、水質監測結合當地觀光、漁業發展，相得益彰。

第五天赴馬里蘭大學環境科學中心 CHESAPEAKE BIOLOGICAL LABORATORY（CBL），瞭解河域生態環境監測、水質實驗室運作及當地民眾教育宣導情形。

CBL 是馬里蘭大學環境科學中心 3 個姐妹實驗室之一，其使命爲透過與各大學、地方環保單位、國家科學單位、國際科學機構及當地居民之合作研究，達到海洋研究、教育及公共服務等三重任務。CBL 致力於 3 大領域，提供教育研究，包括生態系統物種間之交互作用、環境化學及毒物流布、水產科學等。CBL 的遊客中心，自 1998 年啓用，展示最新科學研究資訊，迄今已訓練超過 60 名解說員，宣導累計超過 2 萬名訪客，主辦超過 65 場研討會，對科學、教育及當地漁業、觀光，均有極大貢獻。

此外，海洋科技聯合會（ACT，由 NOAA 提供經費之合作團體）也將總部設於 CBL，支援水資源管理與永續利用之國家目標，維護保育生態系統的健康，降低對自然界之危害，以及確保公共健康。

隨著汽機車、工業、發電廠排放二氧化碳之大量成長，大氣中二氧化碳已明顯增加。二氧化碳除了造成全球暖化，亦造成海洋酸化問題，監測研究估計近 2 百年來，部分海水之 pH 已降約 0.1，其可能影響包括：造成帶殼類生物缺乏碳酸鈣、影響海水成份、生物因無法長出外殼而死亡，而

珊瑚、牡蠣之生長亦受水質酸鹼度影響。雖然目前這些影響似乎很細微，但是，微小的食物鏈變化，長時間卻可能衍生對生態系造成不可逆轉的災難。

在重金屬研究方面，則研究最簡單的海洋生物--海草，對水質重金屬的攝取與釋出，模擬在不同環境條件下，重金屬在海水和微粒間之交互作用，研析重金屬如何藉由河川、地下水傳輸，從陸地傳送到海洋，並發展新的分析技術，來測定自然水體中極低的重金屬濃度。

馬里蘭大學結合當地生態特色、環境保護、民眾、觀光需求所發展的教育加值模式，成效豐富，可爲國內研究機構仿效。（相關照片如圖 8 至 10、資料如附錄四）

參、心得與建議事項

一、我國亟需擴充氣象、模式專長人力

美國區域性氣象及空氣品質預報，主要由 NOAA 進行，其下設置許多研究團隊，其中大氣資源實驗室(NOAA Reseach/ARL)負責空氣品質、大氣擴散模式、氣象模式之研發與改良；而國家環境預測中心(NOAA/NCEP)則負責預測之執行，該中心環境模式部門(NOAA/NCEP/EMC)進行模式測試驗證後，交由操作部門(NOAA/NCEP/NCO)執行系統維護、例行預報作業等，層層負責。反觀國內現行預報作業，係分由氣象局執行氣象預報、環保署執行空氣品質預報，而環保署限於人力不足，在空氣品質預報發展上，有相當限制，建議能擴充氣象、大氣擴散模式專長人力，成立專職團隊，以提升空氣品質預報能力。

二、未來環資部下應設立專職團隊，統籌辦理氣象預報與空氣品質預報

NOAA/NCEP/EMC 原來主要業務爲氣象預報模式測試與驗證，約 7 年前才開始接手空氣品質預報模式業務。我國如果未能擴充人力，建議將來環資部整合後，能回歸同一單位，並仿效美國區分模式改良、模式測試與驗證、預報操作等專責工作團隊，將有助於空氣品質預報技術之精進與改良。

三、建議與美國持續辦理技術交流

NOAA 有許多其他國家之 1 年交換學者共同工作，例如大陸勞動保護科學研究所、我國氣象局等，均有派員在當地學習與交流，空氣品質預報人員，需具備專精之氣象與大氣模式能力，建議持續進行短期或發展長期之人員培訓，以利我國空氣品質預報技術之長程發展。

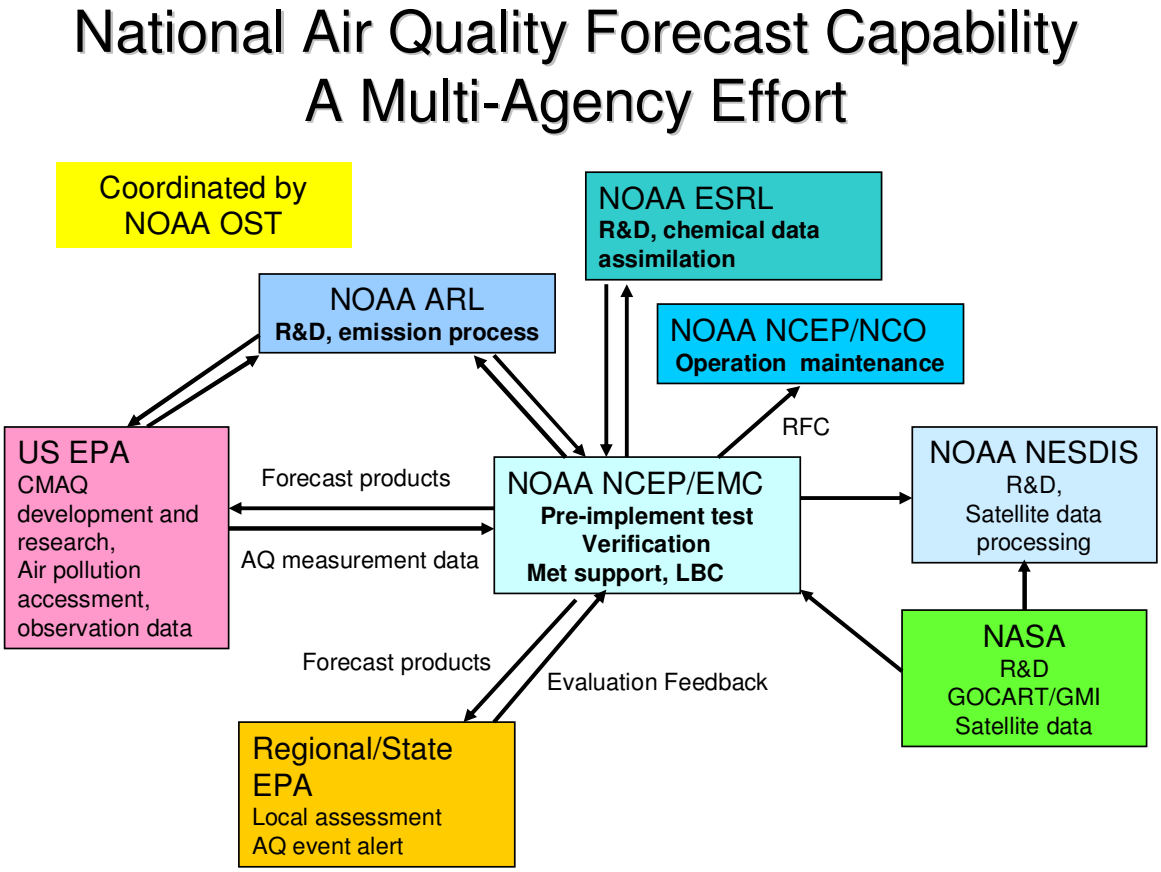


圖 1、美國空氣品質預報—NOAA、EPA、NASA 合作關聯圖

圖 2、ARL 位於 NOAA 總部，大門口手型雕塑爲其地標

圖 3、NCEP 位於南方 1 小時地鐵距離之 NOAA SCIENCE CENTER 大樓（當地位處郊區，治安不佳，晚上 6 時以後勿逗留）

圖 4、在 NOAA's ARL 與部分團隊成員合照

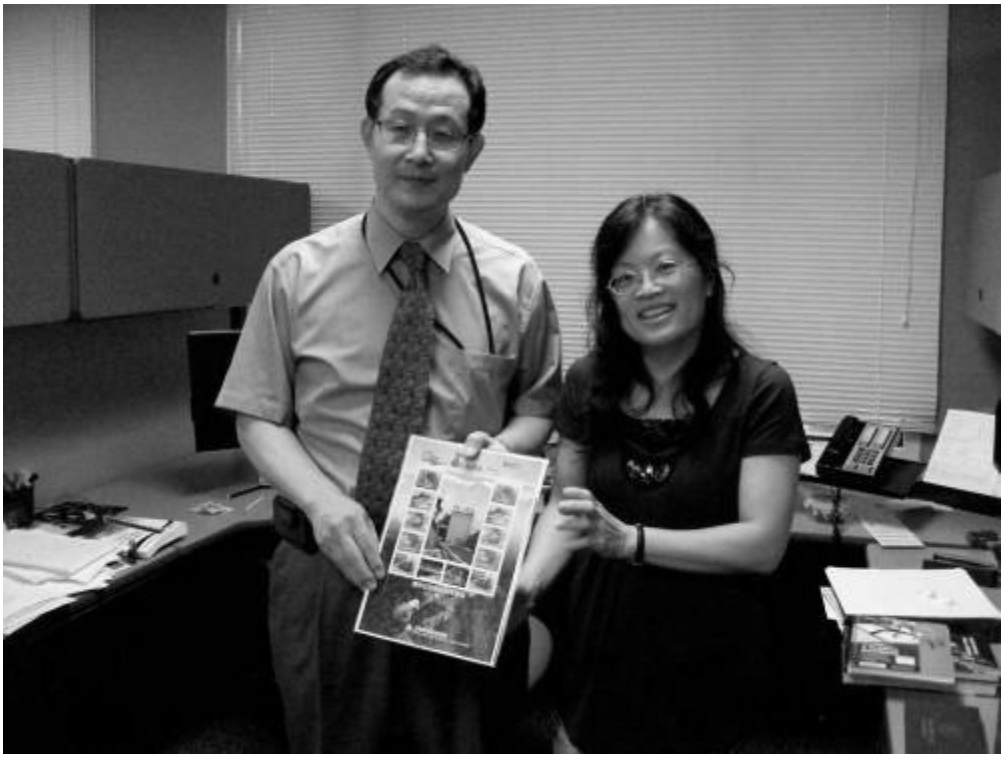


圖 5、在 NOAA's ARL 與 Daewong Byun 合照

圖 6、在 NOAA’s NECP 與 Jeff 合照

圖 7、在 NOAA’s NECP 部分團隊成員合照

圖 8、在馬里蘭大學環境科學中心 CHESAPEAKE，講解人員向參觀民眾說明河域生態監測情形

圖 9、在馬里蘭大學環境科學中心 CHESAPEAKE 生態實驗室，瞭解河域生態環境監測、水質實驗室運作情形

圖 10、在馬里蘭大學環境科學中心 CHESAPEAKE 生態實驗室，與解說員合照

附錄一、Evaluation of NOAA National Air Quality Forecasting Capability for Week of August 16-22, 2010

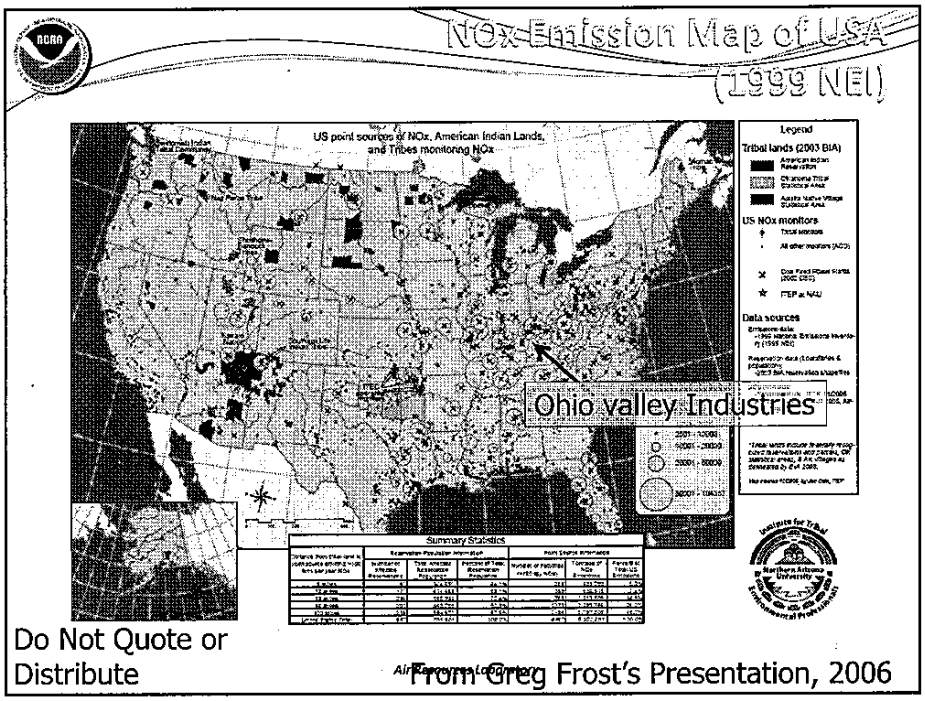
Evaluation of NOAA National Air Quality Forecasting Capability for Week of August 16-22, 2010

Daewon W. Byun
Air Quality Modeling Group

U.S. Dept. of Commerce
National Oceanic & Atmospheric Admin. (NOAA)
Office of Oceanic and Atmospheric Research
Air Resources Laboratory
Headquarters

Objectives

- Perform weekly evaluation of NAQFC to review air quality model performance under different weather conditions
- Develop conceptual models of high pollution events for different regions of USA
- Study how the meteorological model inputs affect biases in the air quality model predictions
- Identify shortcomings of individual science processes under particular weather conditions
- Solicit ideas to improve model performance


NOx Emission Map of USA
(1999 NEI)
US point sources of NOx, American Indian Lands, and Tribes monitoring NOx
Legend
Tribal lands (2003 BIA)
US NOx monitors
Data sources
Ohio valley Industries
Summary Statistics
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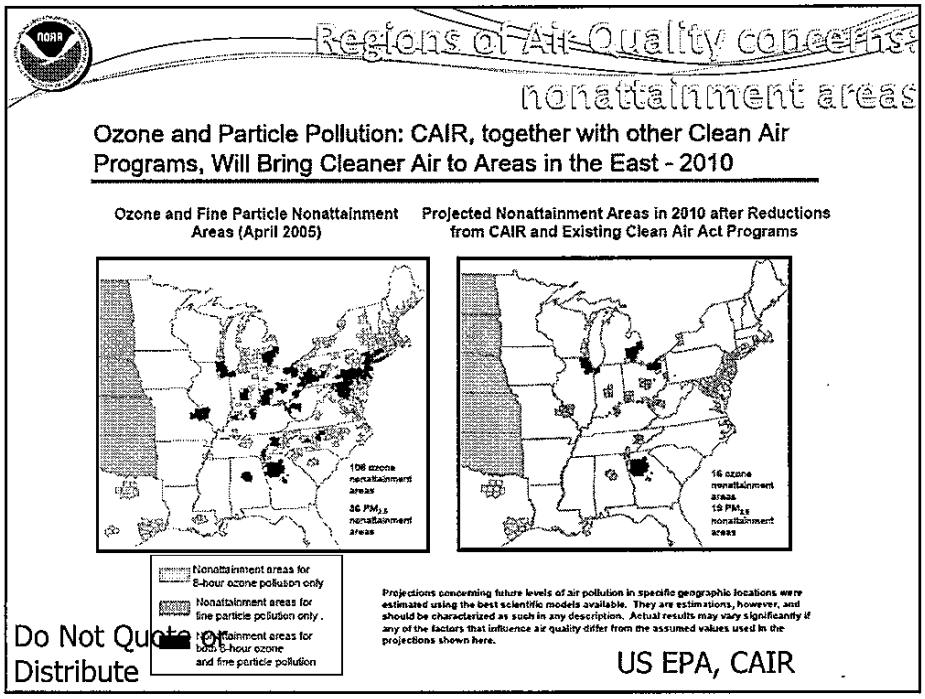
From Greg Frost's Presentation, 2006


Regions of Air Quality concern:
nonattainment areas
Ozone and Particle Pollution: CAIR, together with other Clean Air Programs, Will Bring Cleaner Air to Areas in the East - 2010
Ozone and Fine Particle Nonattainment Areas (April 2005)
Projected Nonattainment Areas in 2010 after Reductions from CAIR and Existing Clean Air Act Programs
Nonattainment areas for 8-hour ozone pollution only
Nonattainment areas for fine particle pollution only
Nonattainment areas for both 8-hour ozone and fine particle pollution
Projections concerning future levels of air pollution in specific geographic locations were estimated using the best scientific models available. They are estimations, however, and should be characterized as such in any description. Actual results may vary significantly if any of the factors that influence air quality differ from the assumed values used in the projections shown here.
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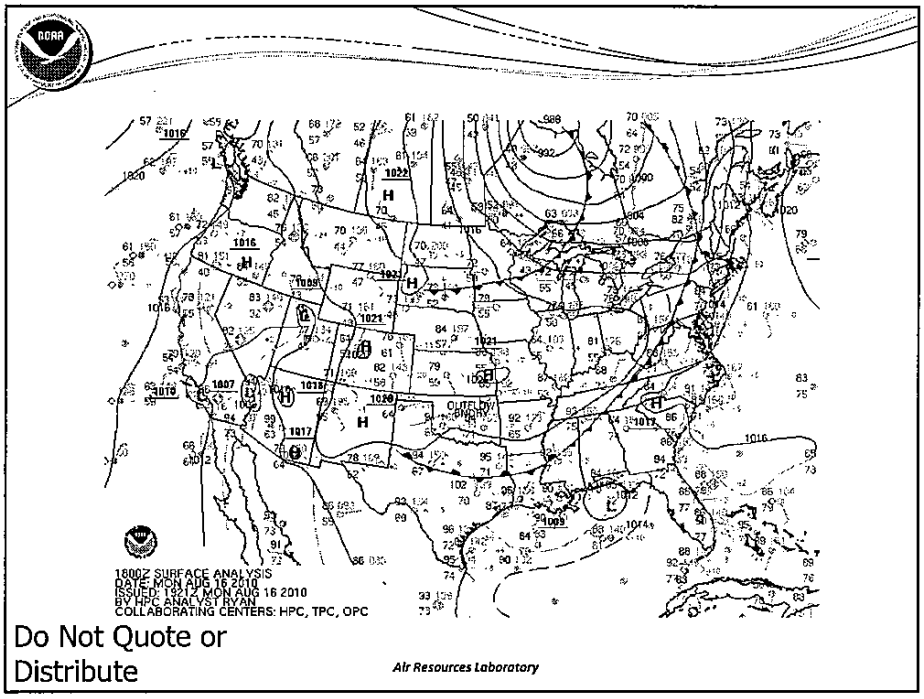
US EPA, CAIR


1600Z SURFACE ANALYSIS
DATE: MON AUG 16 2010
ISSUED: 1912Z MON AUG 16 2010
BY HPC ANALYST RYAN
COLLABORATING CENTERS: HPC, TPC, OPC
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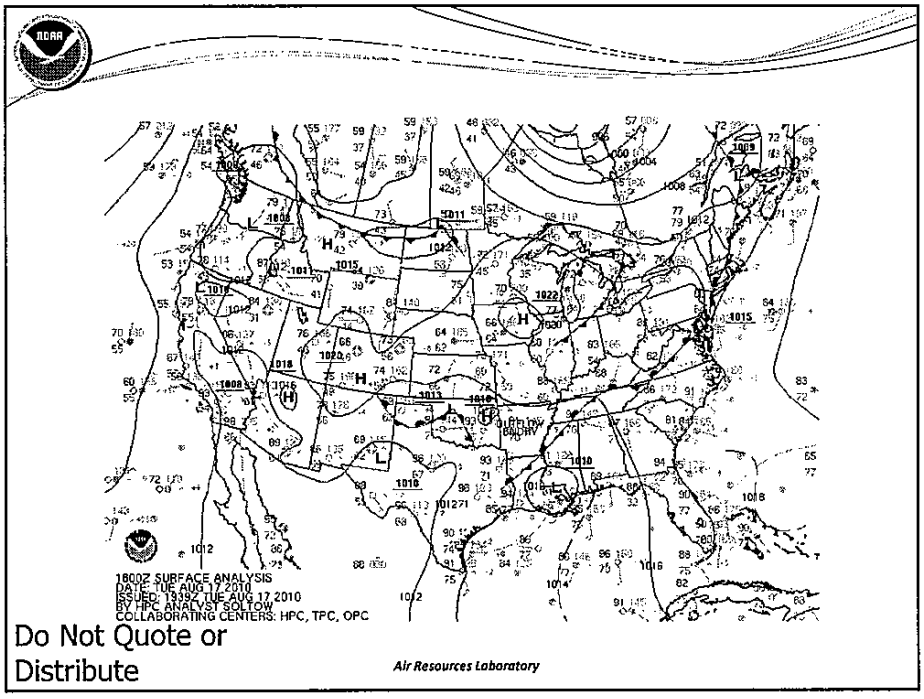
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ISSUED: 1919Z TUE AUG 17 2010
BY HPC ANALYST SOLTOW
COLLABORATING CENTERS: HPC, TPC, OPC
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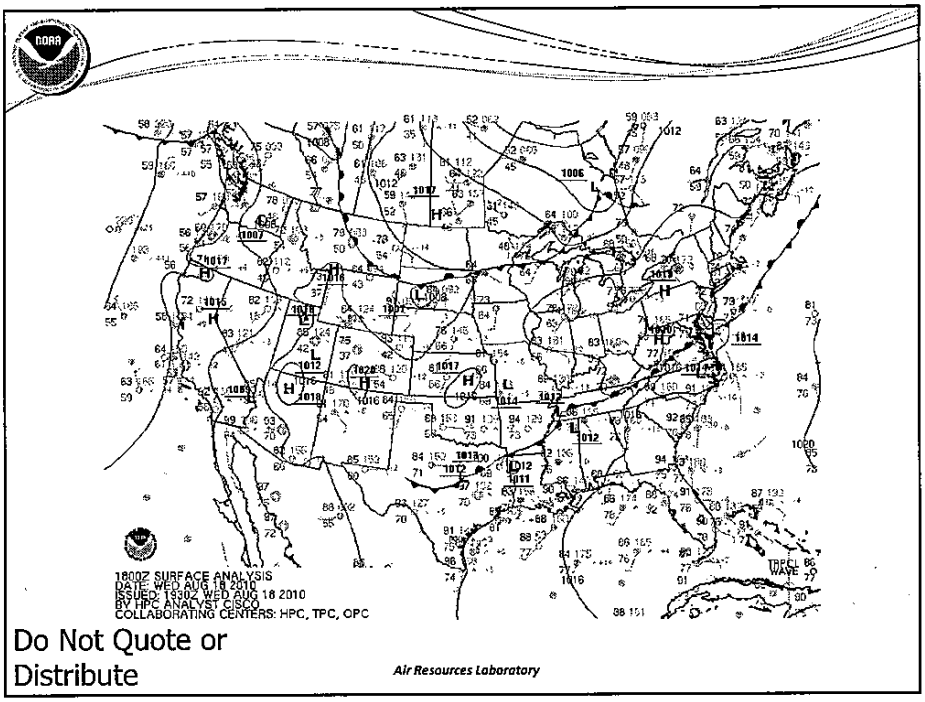
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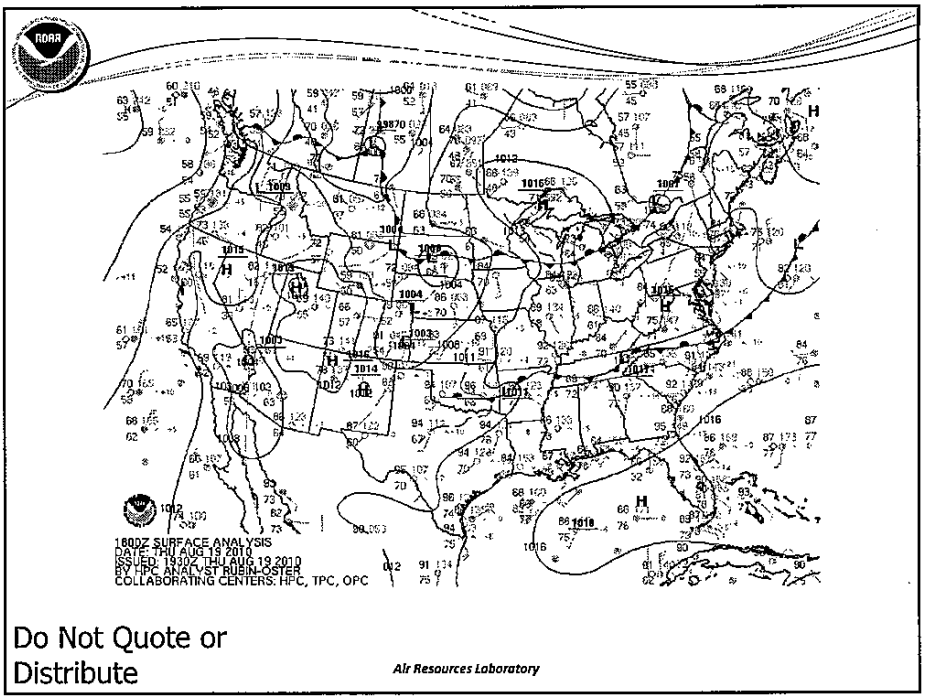
Do Not Quote or Distribute
Air Resources Laboratory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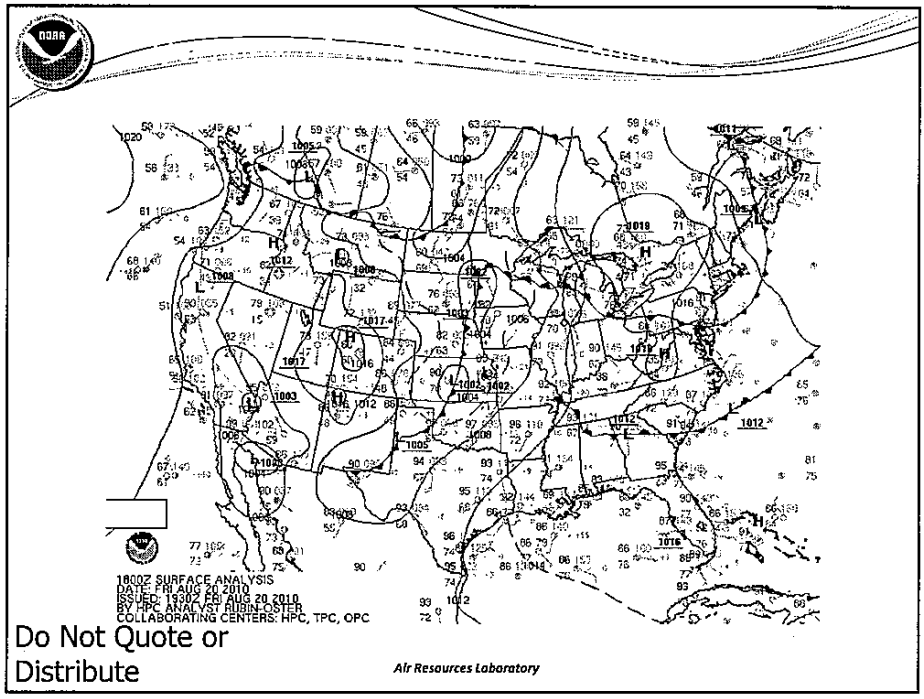
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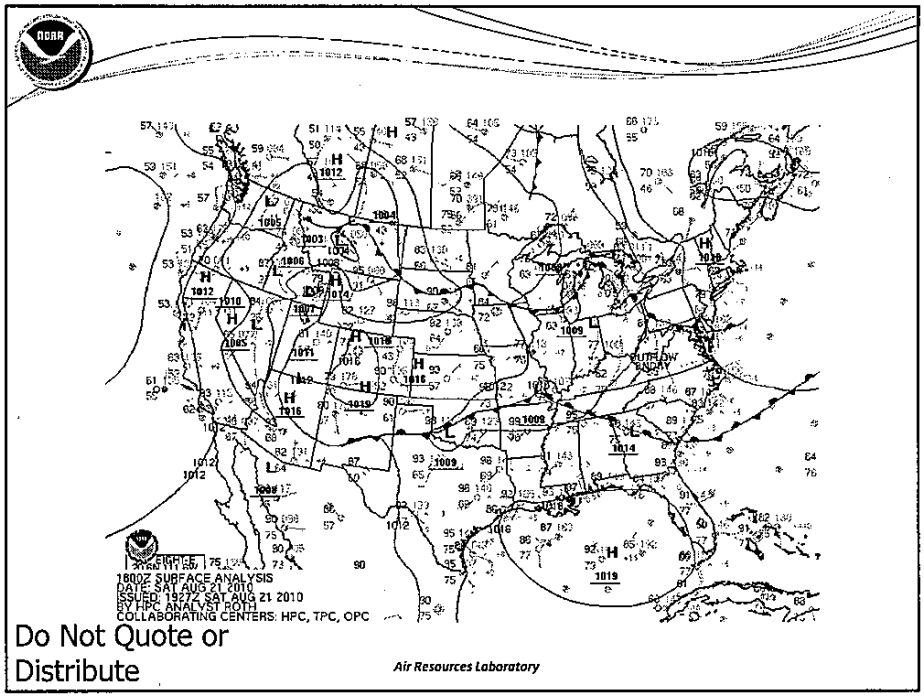
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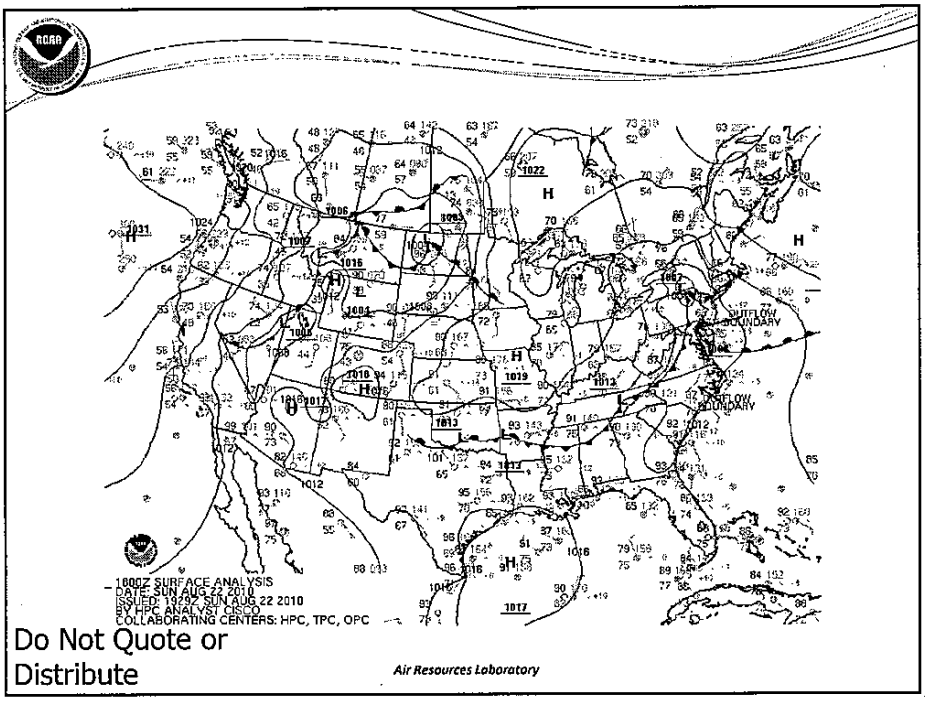
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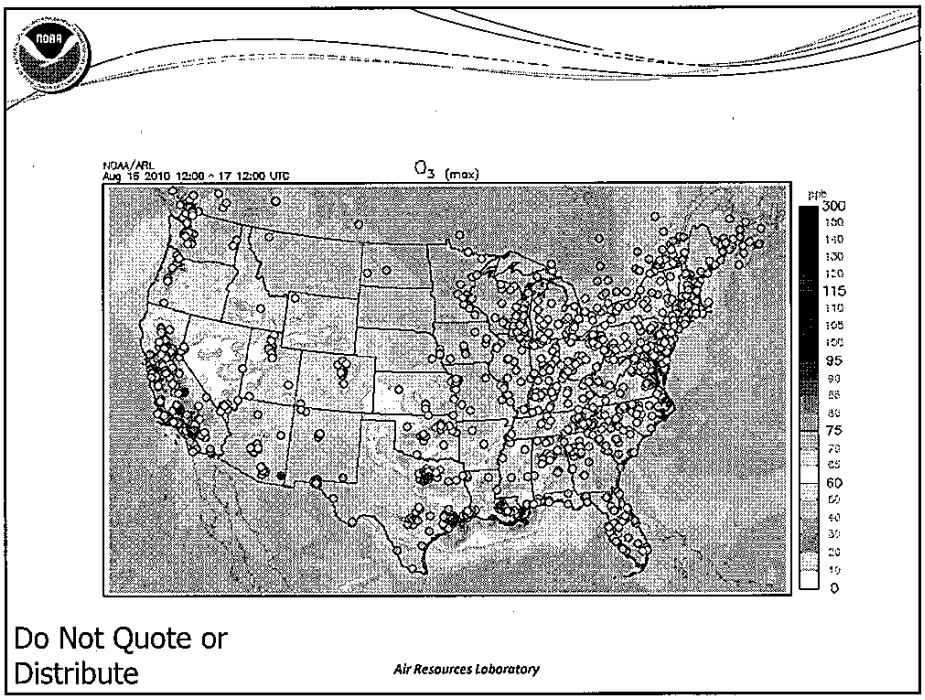
OUTFLOW BOUNDARY
Do Not Quote or Distribute
Air Resources Laboratory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PPB
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120
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110
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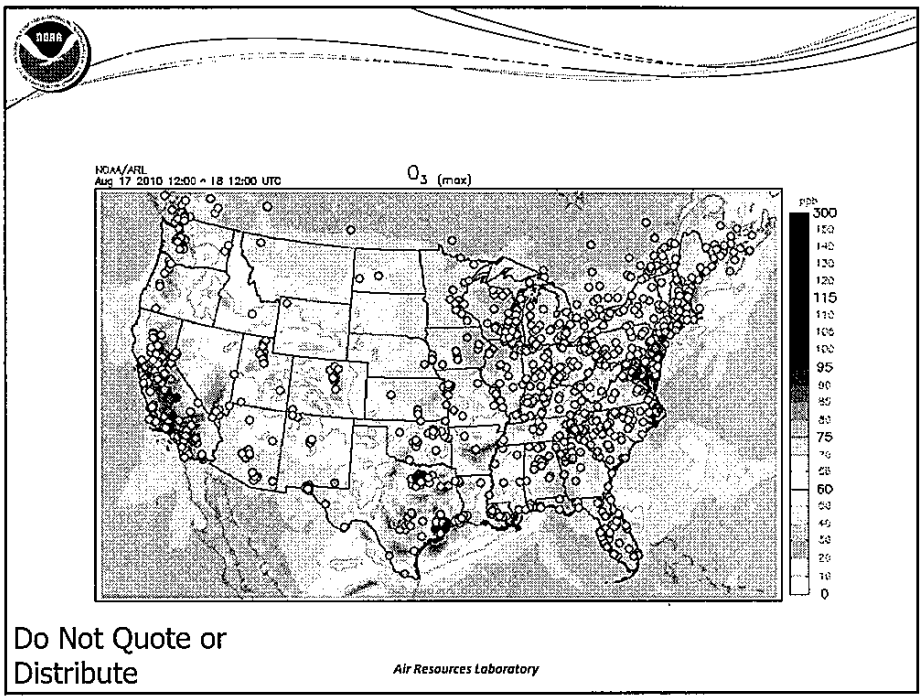
Do Not Quote or Distribute
Air Resources Laboratory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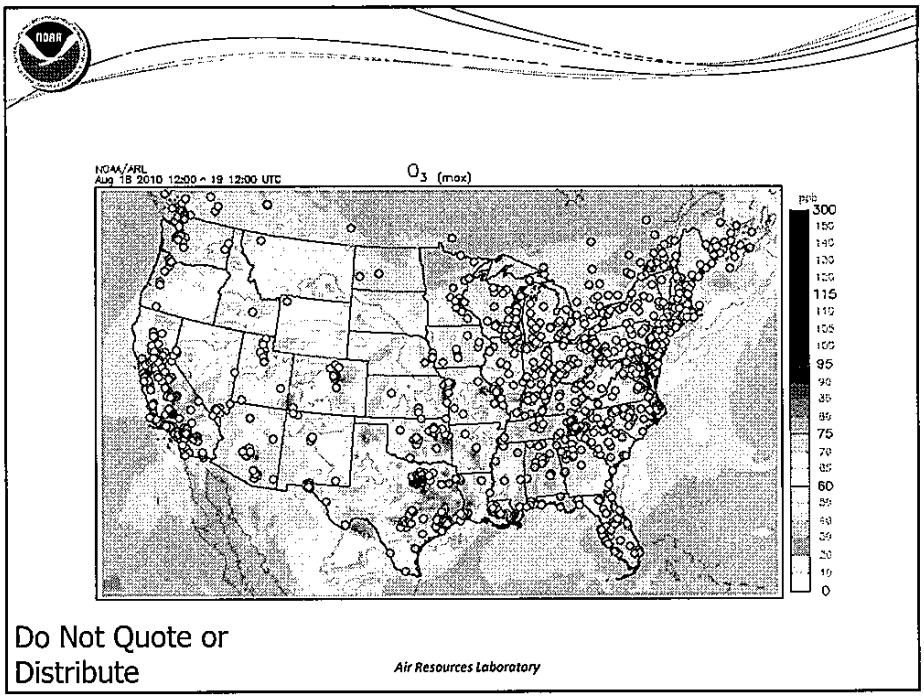
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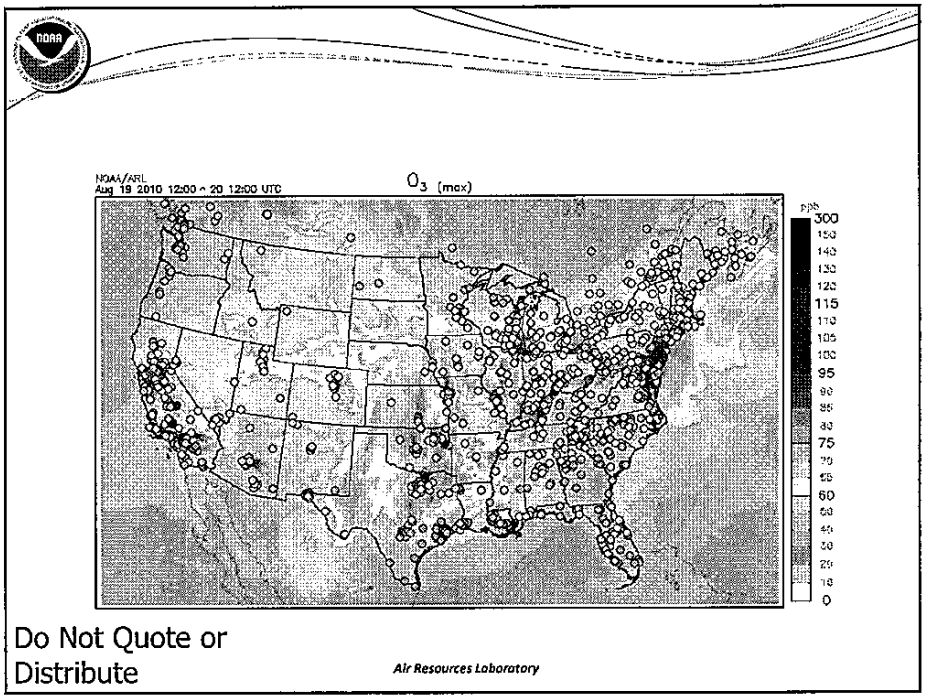
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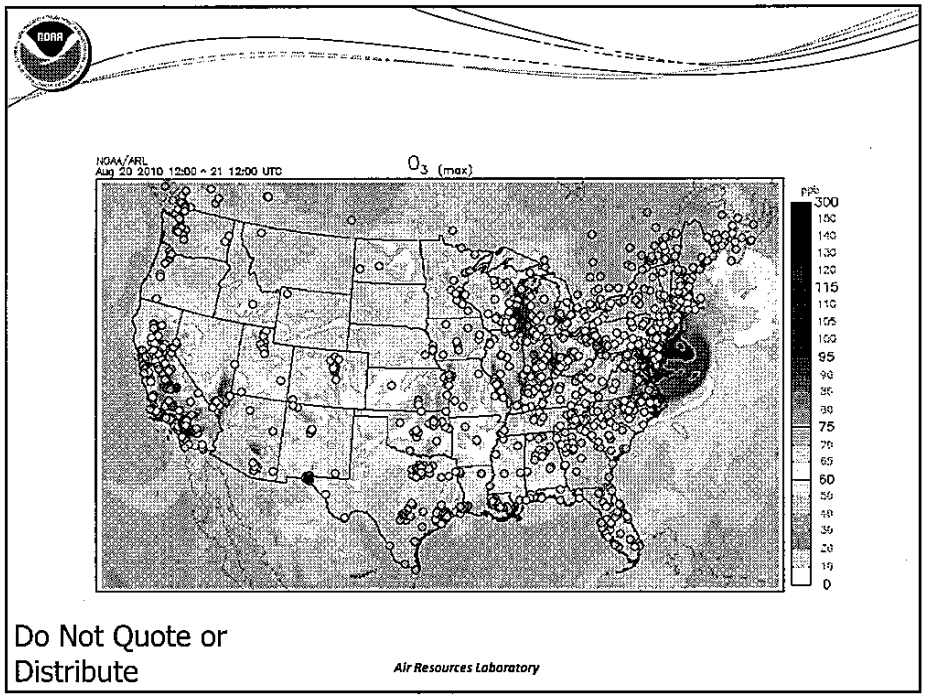
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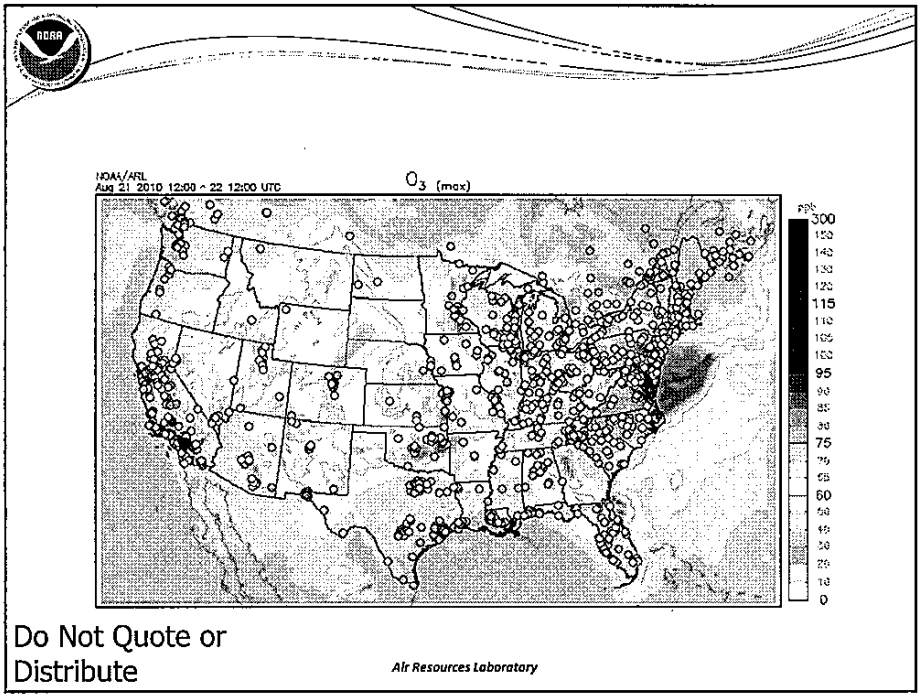
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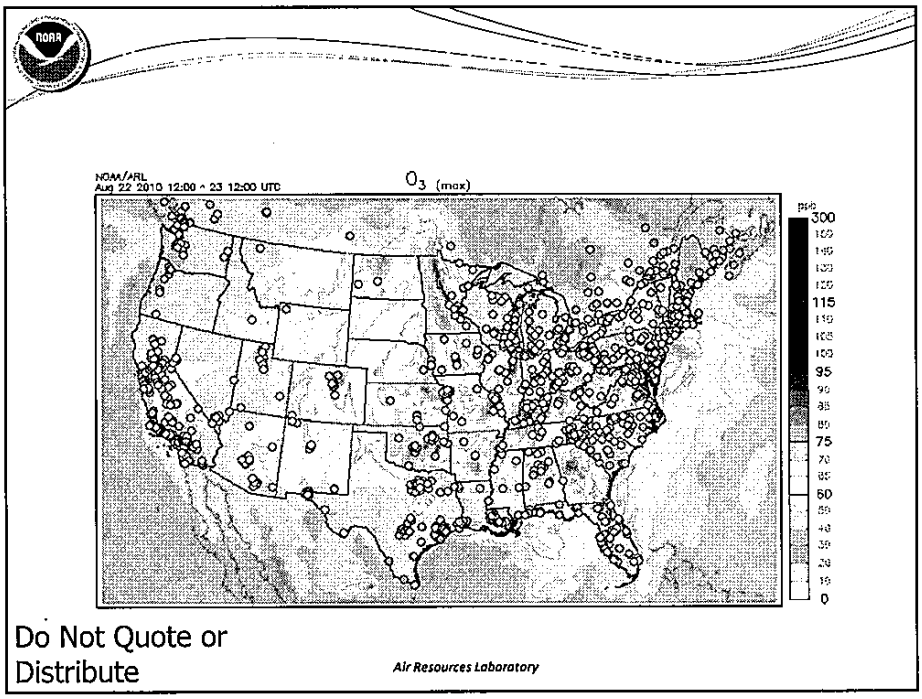
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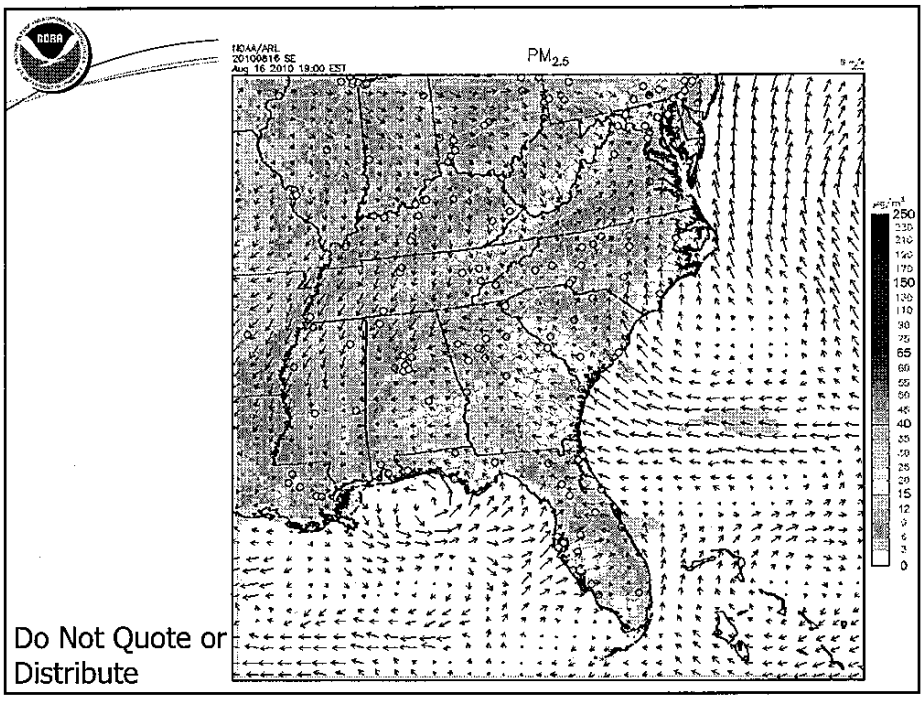
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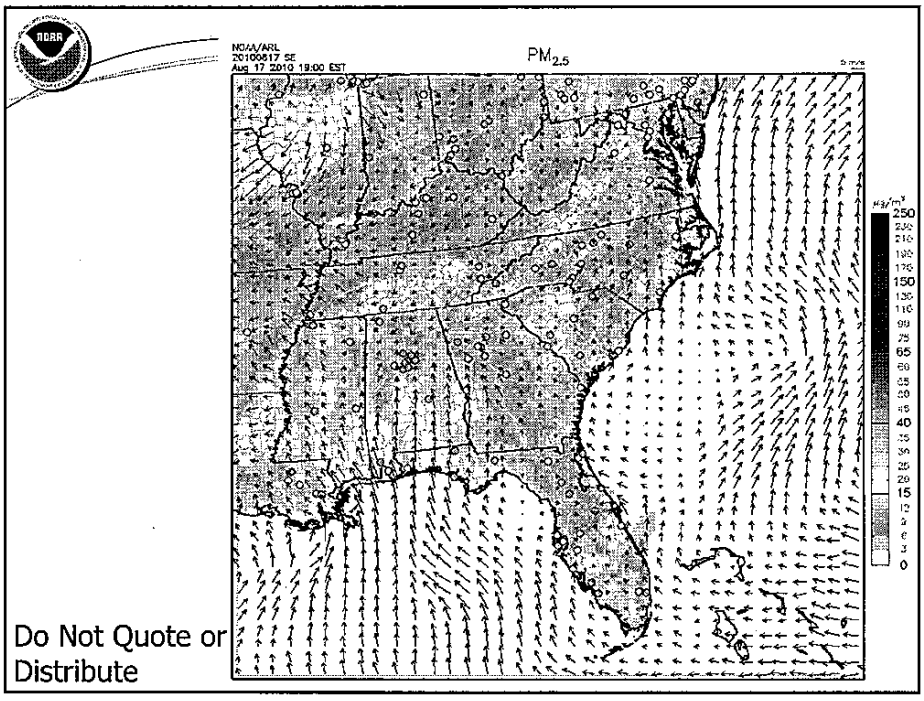
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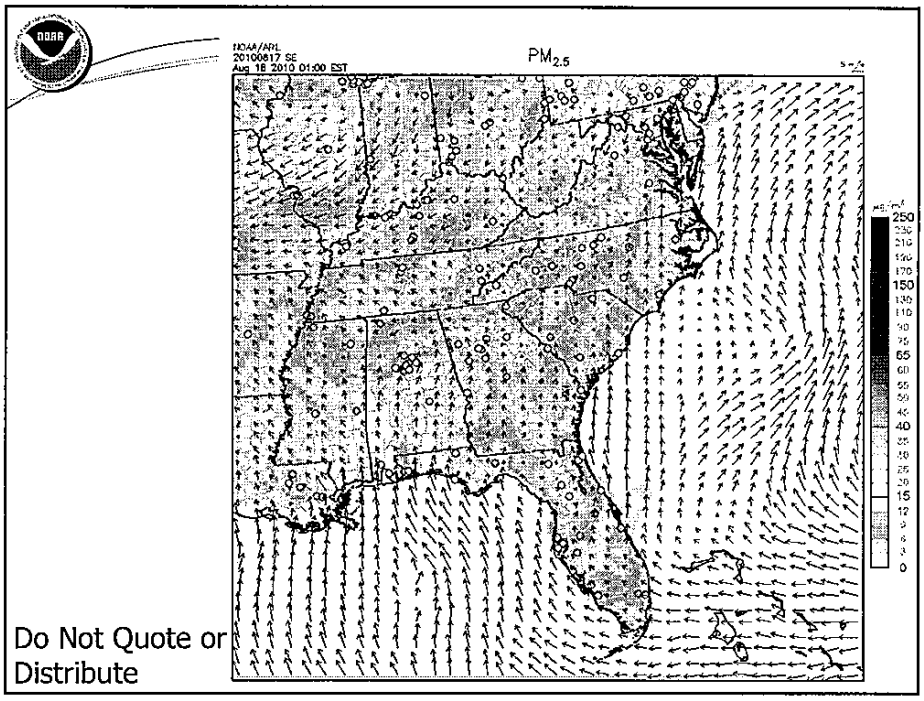
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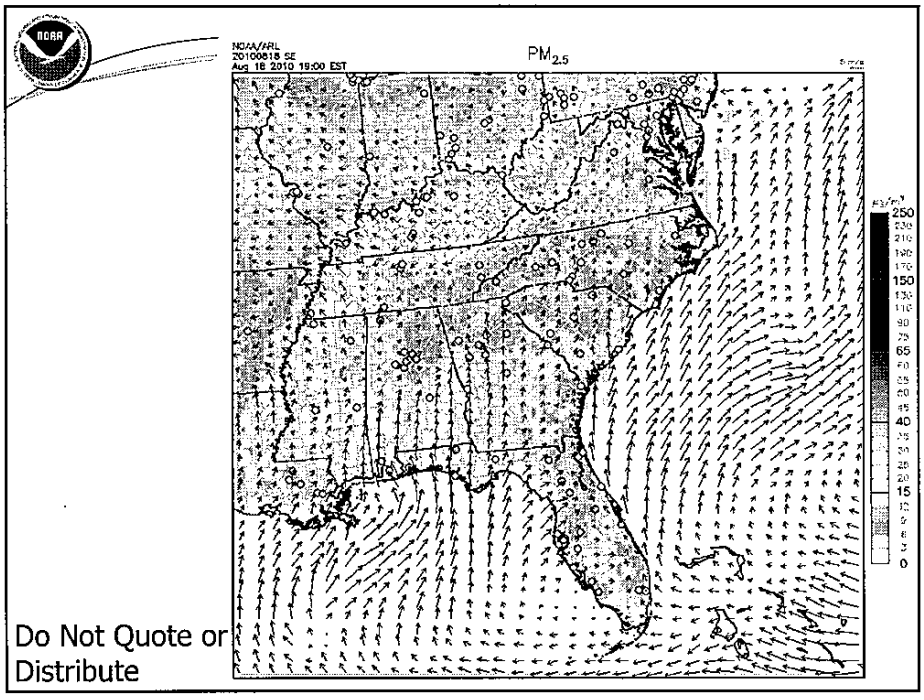
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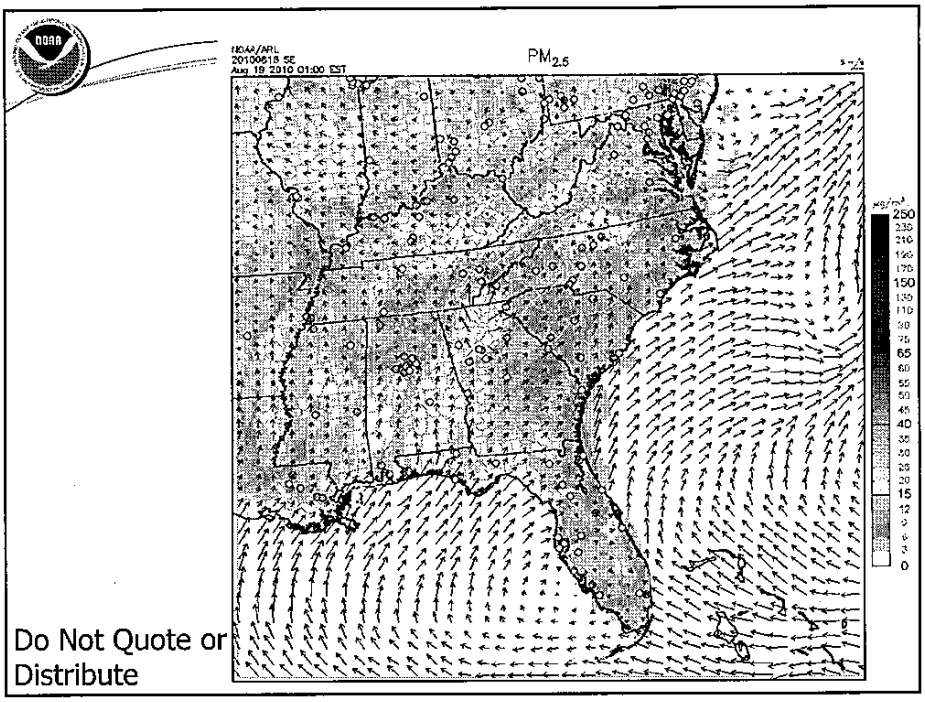
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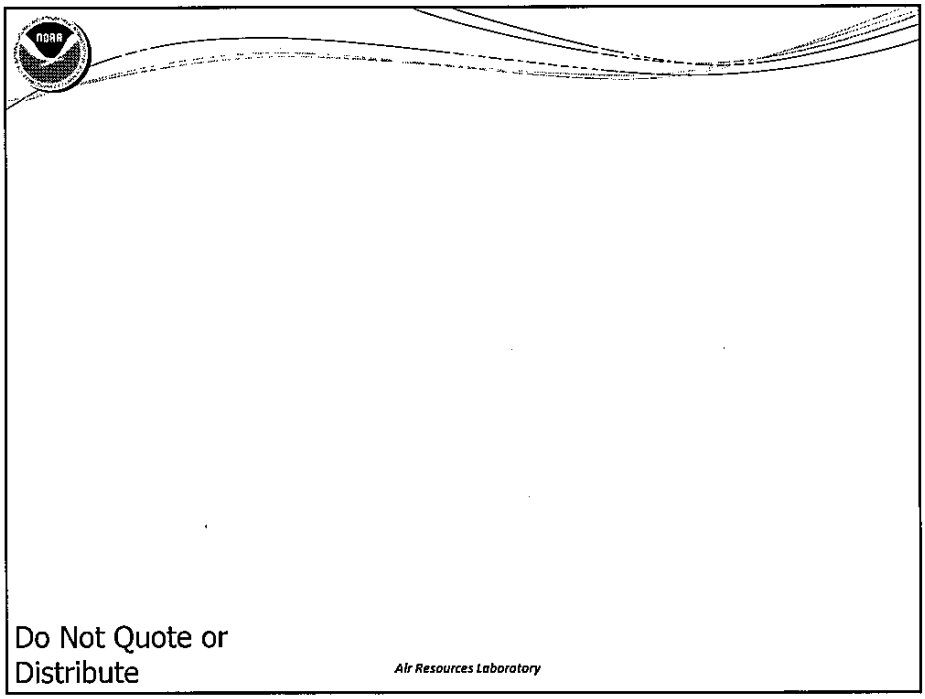
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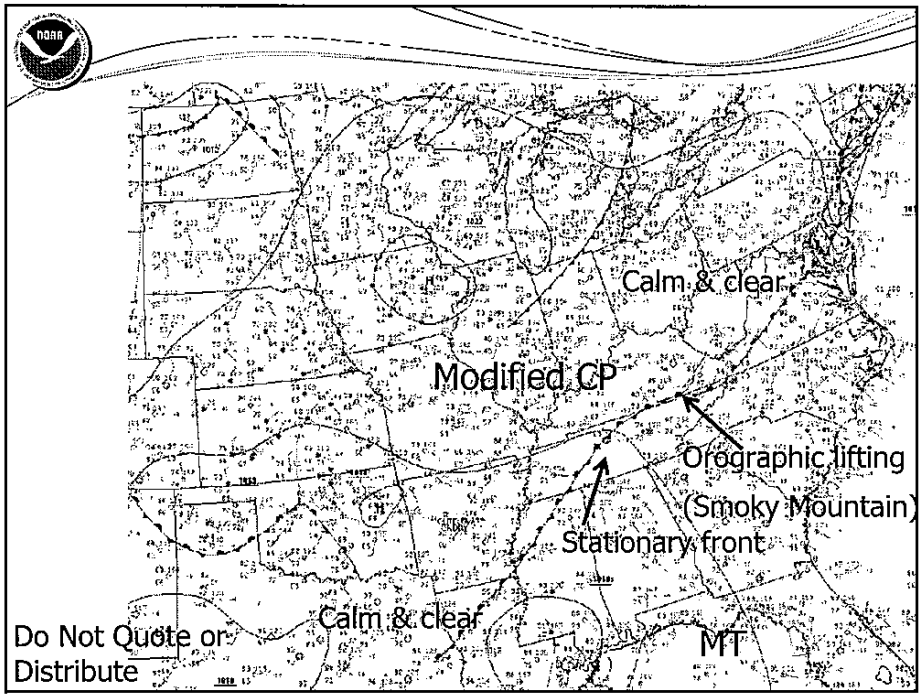
Calm & clear
Modified CP
Orographic lifting
(Smoky Mountain)
Stationary front
Calm & clear
MT
Do Not Quote or
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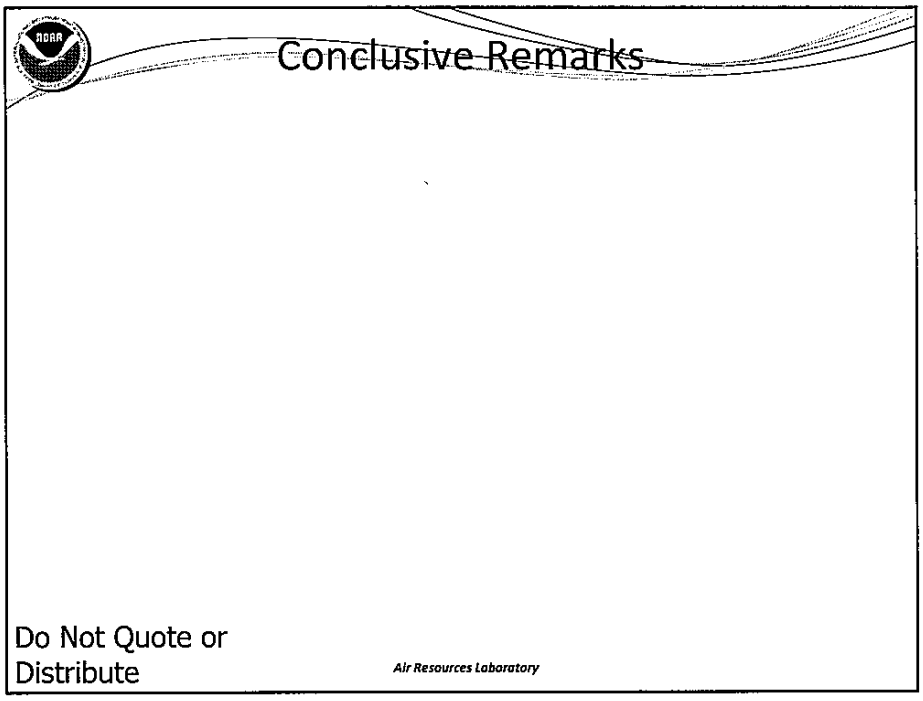
Conclusive Remarks
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Air Resources Laboratory

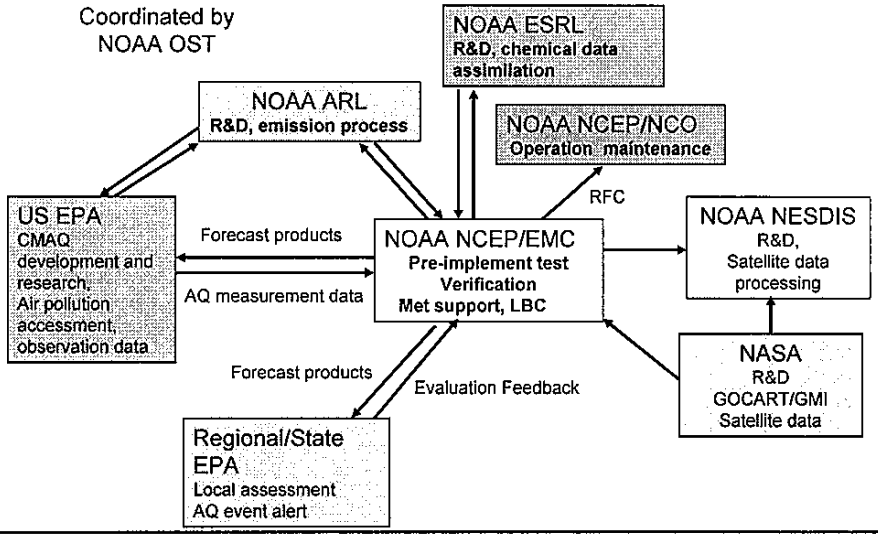
附錄二、Regional Air Quality Forecasting in NOAA/NWS/NCEP

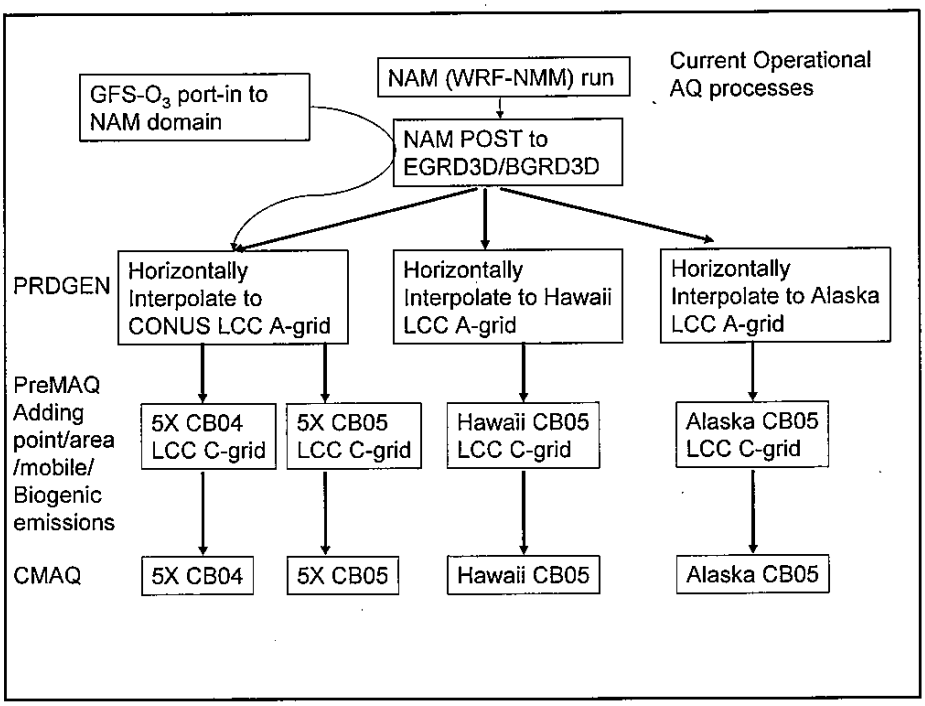
Regional Air Quality Forecasting in NOAA/NWS/NCEP

EMC/AQ

Wednesday, August 25, 2010

National Air Quality Forecast Capability
A Multi-Agency Effort



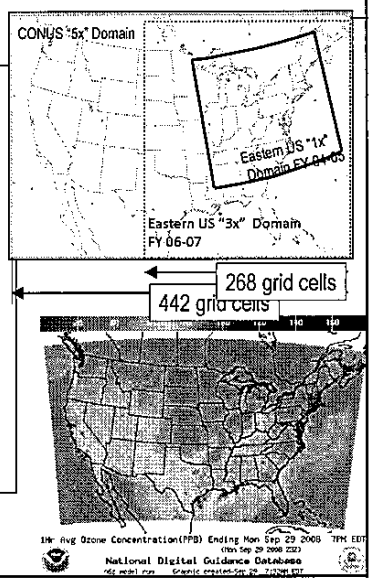


NAQFC Configurations

Emissions:
- EPA CEM anthropogenic inventories
- 2005 base year projected to current year w/ EGU
- BEIS V3 Biogenic Emissions

Met Model:
- North American Model (NMM)
- Non-hydrostatic Multi-scale Model (NMM)
- 12 km 60 Levels

AQ Model:
- EPA Community Model For Air Quality
  - CMAQ V4.6: 12 km/L22 CONUS Domain
  - Oper: CB04 gas-phase
  - Exper/Dev: CB05/ Aero-4 aerosols
- Output available on National Digital Guidance Database
  - 48 hour forecasts from 06/12 UTC Cycles

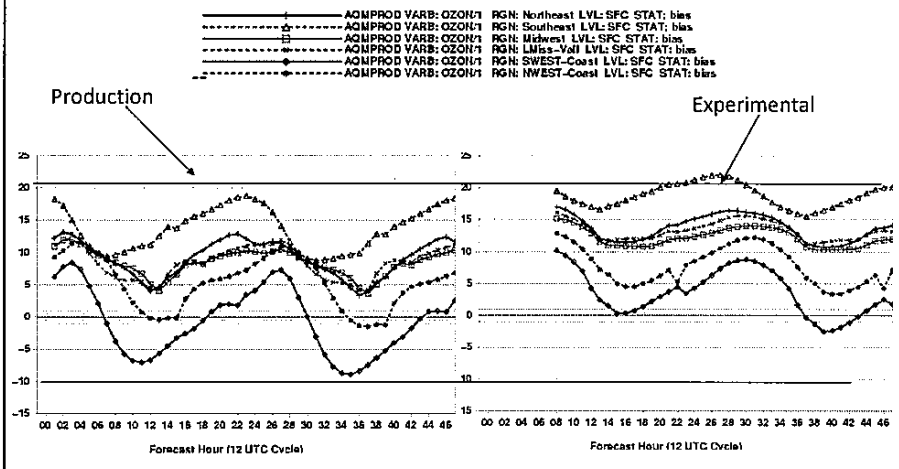


Timing line of NAQFC (NCO, prod)

Cycle	NAM	PreGen	PreMAQ	CMAQ	Post	Verif.	NDGD
00z (6h)	03z	< 5min	<5 min	10 min	<5 min		
06z (48h)	09z	35 min	26 min	80 min (nodes ?)	<5 min		13:00 Z (9amEDT)
12z (48h)	15z	The same as 06z	The same as 06z	The same as 06z	The same as 06z		17:25 Z (1:25 pm EDT)
18z (6h)	21z	The same as 00z	The same as 00z	The same as 00z	The same as 00z		

Note: all used time relies on computer resources

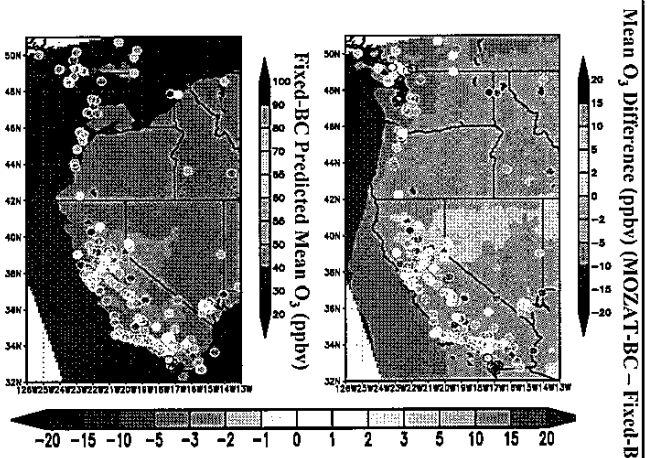
NCEP Air Quality Forecast 2009 Verification
(8 hr avg ozone bias)



Almost the same for NW and Mid West
Higher for NE, SE and Low Miss Valley (increase positive bias)
Higher for SW (improve negative bias)

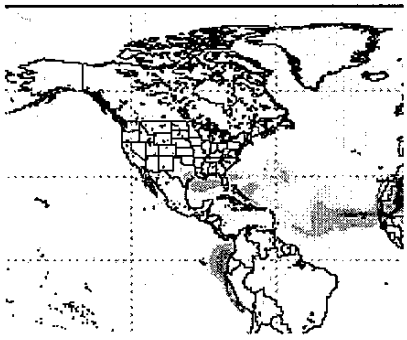
Impact on ozone prediction due to the regional model coupling with global models via lateral boundary condition.

	All Stations	West of -115°W
Fixed LBC	S=0.887 R=0.714 MB=8.0 ppbv	S=0.804 R=0.691 MB=4.7 ppbv
RAQMS LBC	S=0.911 R=0.718 MB=10.0 ppbv	S=0.914 R=0.703 MB=7.1 ppbv
MOZART LBC	S=0.941 R=0.716 MB=8.2 ppbv	S=0.872 R=0.730 MB=2.2 ppbv
GFS O_3 LBC	S=0.835 R=0.714 MB=0.2 ppbv	S=0.820 R=0.697 MB=-4.8 ppbv
IONS LBC1	S=0.947 R=0.718 MB=12.4 ppbv	S=0.912 R=0.682 MB=10.4 ppbv

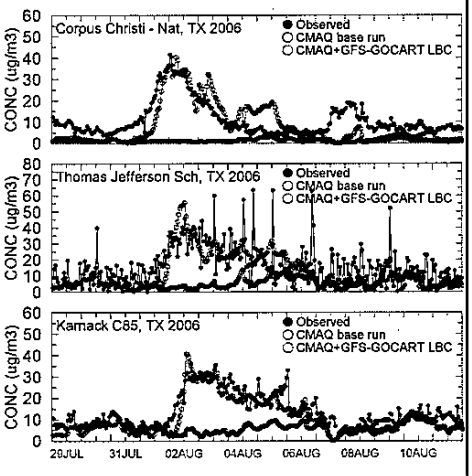


Mean O_3 bias (ppbv) Compared to EPA Airnow data
Aug 1-5, 2006

Improved PM predictions with GFS-GOCAR LBCs



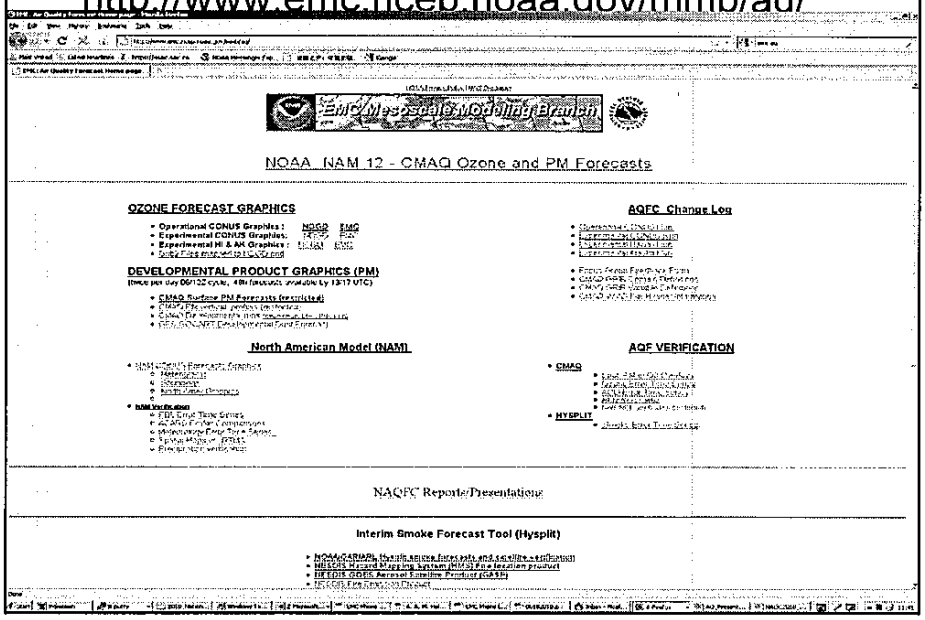
- During Texas Air Quality Study 2006, the model inter-comparison team found all 7 regional air quality models missed some high-PM events, due to trans-Atlantic Saharan dust storms.
- These events are re-visited here, using dynamic lateral aerosol boundary conditions provided from dust-only off-line GFS-GOCART.



Youhua Tang and Ho-Chun Huang (EMC)

Source:

http://www.emc.ncep.noaa.gov/mmb/aq/



附錄三、Overview of The Environmental Modeling Center

Overview of The Environmental Modeling Center

Stephen J. Lord
Director
NCEP Environmental Modeling Center

NCEP: "where America's climate, weather, and ocean services begin"

Overview

- EMC organization
- Role of models in the forecast process
- Strategic highlights
  - Mesoscale system consolidation (WRF)
  - Next-generation
    - Global forecast model (ESMF)
    - Data assimilation (JCSDA)
  - Daily ocean forecasting (HYCOM)
  - Hurricanes (HWRF)
  - Ensembles (NAEFS, SREF, THORPEX)
  - Land surface modeling and hydrology (GAPP)
- Proposed strategic plan elements
- Summary

EMC Mission

In response to operational requirements:

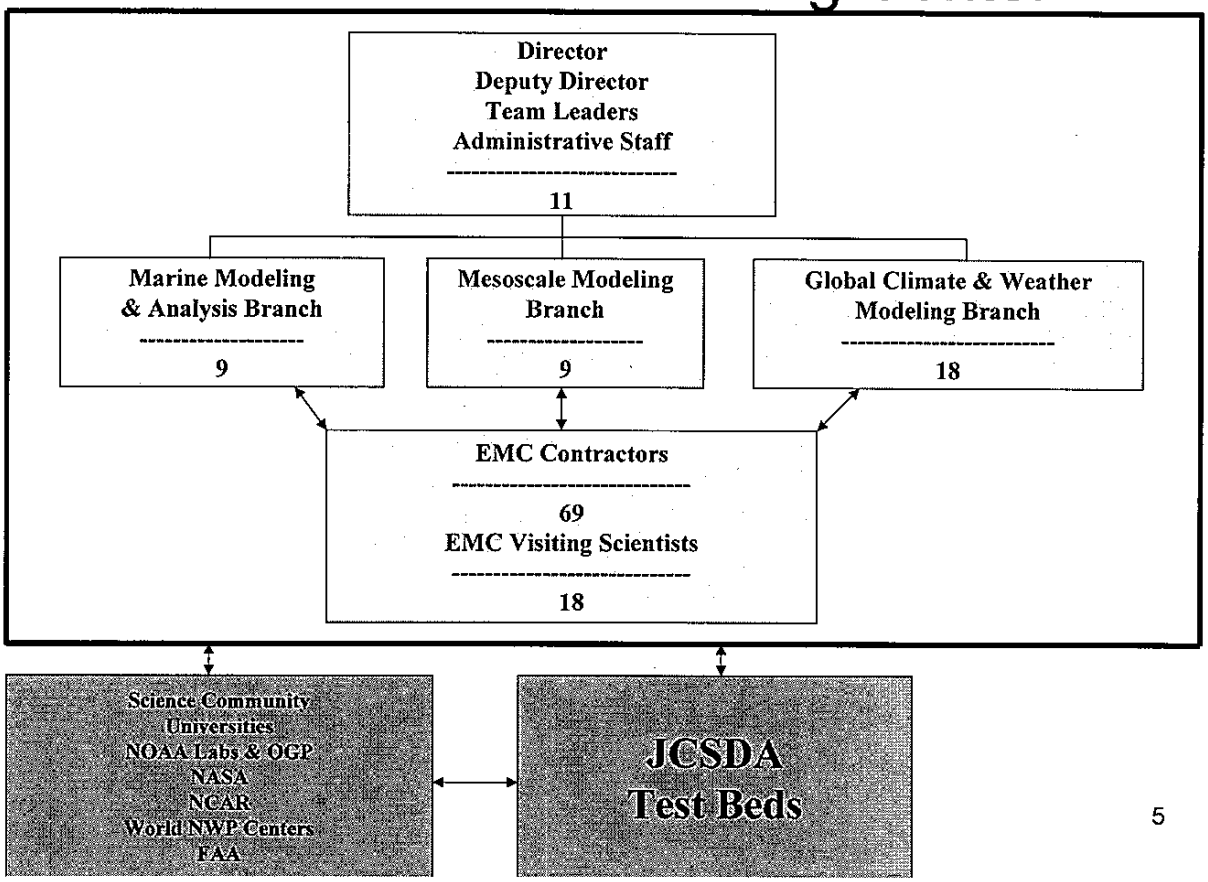
- Maintain the scientific correctness and integrity of operational forecast systems
  - Adapt to format changes and other changing operational requirements
  - Adapt to new computing hardware
  - Monitor and ensure the integrity of operational observing systems
- Enhance (Test & Improve) Numerical Forecasts Through Advanced
  - Data assimilation techniques
  - Model physics (parameterizations)
  - Numerical methods
  - Computational efficiency
- Transition and Develop Operational Numerical Forecast Systems for:
  - Weather prediction (domestic, global, 1-15 days)
  - Ocean prediction (daily to annual, coastal to global)
  - Climate prediction (seasonal to inter-annual)

Maintain: Modify current operational system to adapt to ever-present external changes	**Enhance**: Test and improve NCEP's numerical forecast systems via scientific upgrades, tuning, additional observations, in response to user requirements	**Transition and Develop**: transform & integrate code, algorithms, techniques from research status to operational status on NCEP computers

Mission Requirements & Forecast Suite Elements

Suite Elements	Global NWP	Reg. NWP	Fire Wx Rapid Update Reg. Hurricane	Air Quality	Global Ensembles	Regional Ensembles	Real Time Ocean	S/I Climate
NCEP	X	X	X	X	X	X	X	X
UKMO	X	X		X		X	X	
ECMWF	X				X			X

Environmental Modeling Center



Environmental Modeling Center Service-Science Linkage

Service

Marine & Coastal Ocean DB Rao	Mesoscale Atmosphere G. DiMego	Global Climate & Weather Atmosphere & Ocean M. Iredell	**Science**
X	X	X	**Data Assimilation** Leader: J. Derber
	X	X	**Climate** Leader: H.-L. Pan
X	X	X	**Model** Atmosphere/Ocean/Ice Dynamics Physics
X	X	X	**Land Surface/Hydrology** Leader: K. Mitchell
X	X	X	**Ensembles & Probabilistic Guidance** Leader: Z. Toth
X	X	X	**Hurricanes** Leader: N. Surgi
X	X	X	**Products** Development Utilization

Overview

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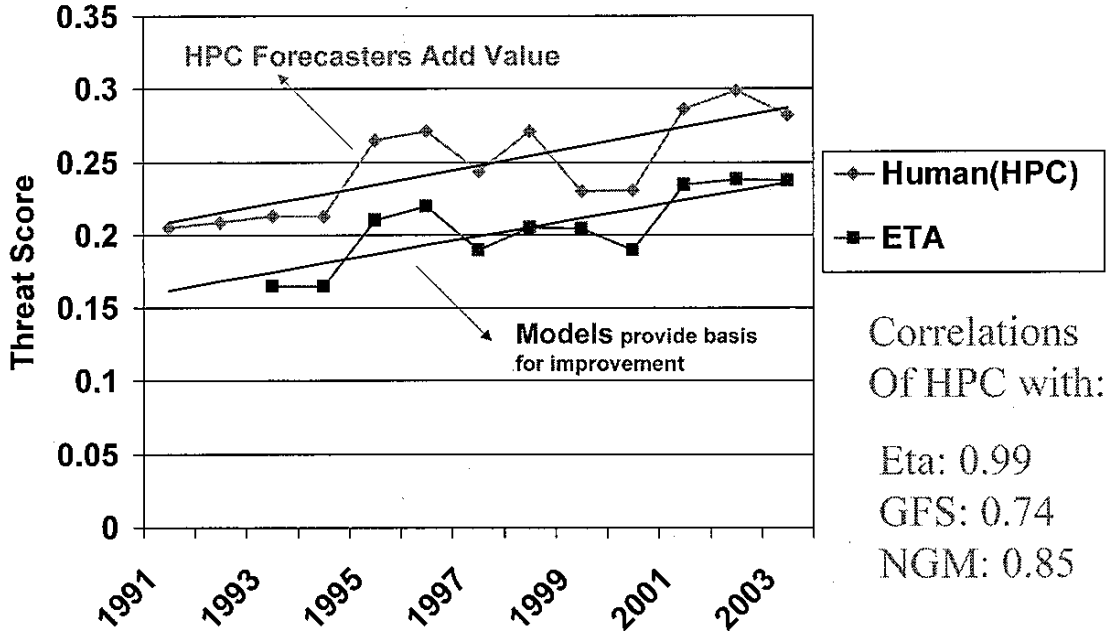
- Proposed strategic plan elements
- Summary

Why Models?

"As go the models, so go the forecasts"

Impact of Models on Day 1 Precipitation Scores

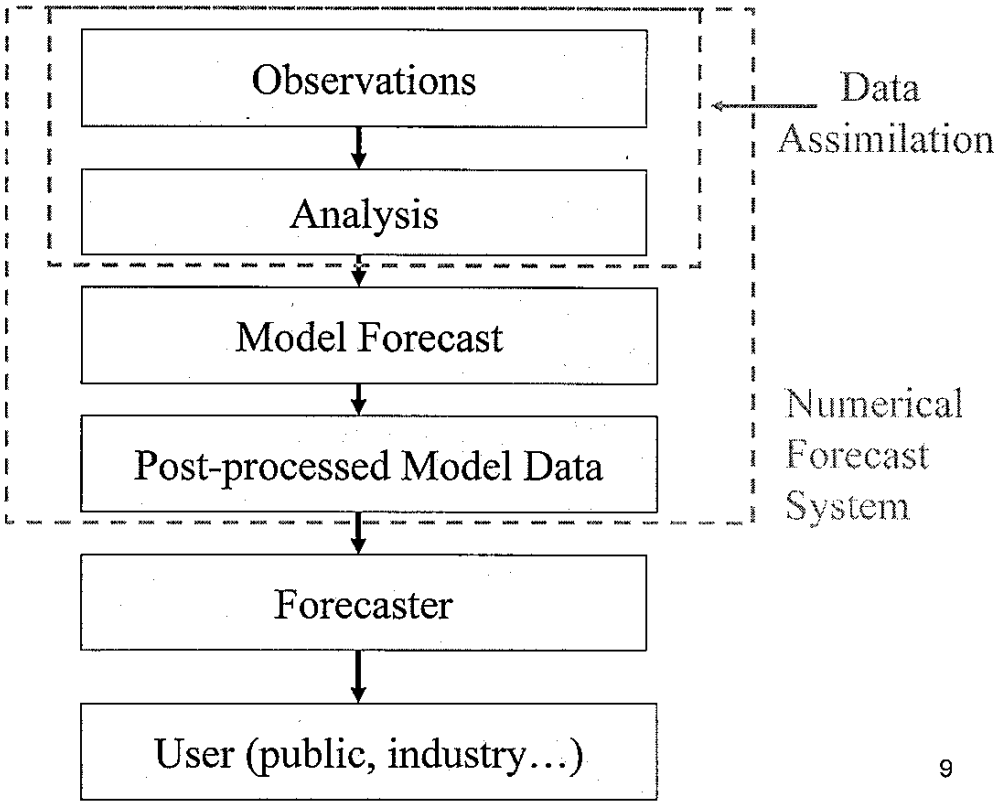
(DOC GPRA goal)



Correlations Of HPC with:

Eta: 0.99
GFS: 0.74
NGM: 0.85

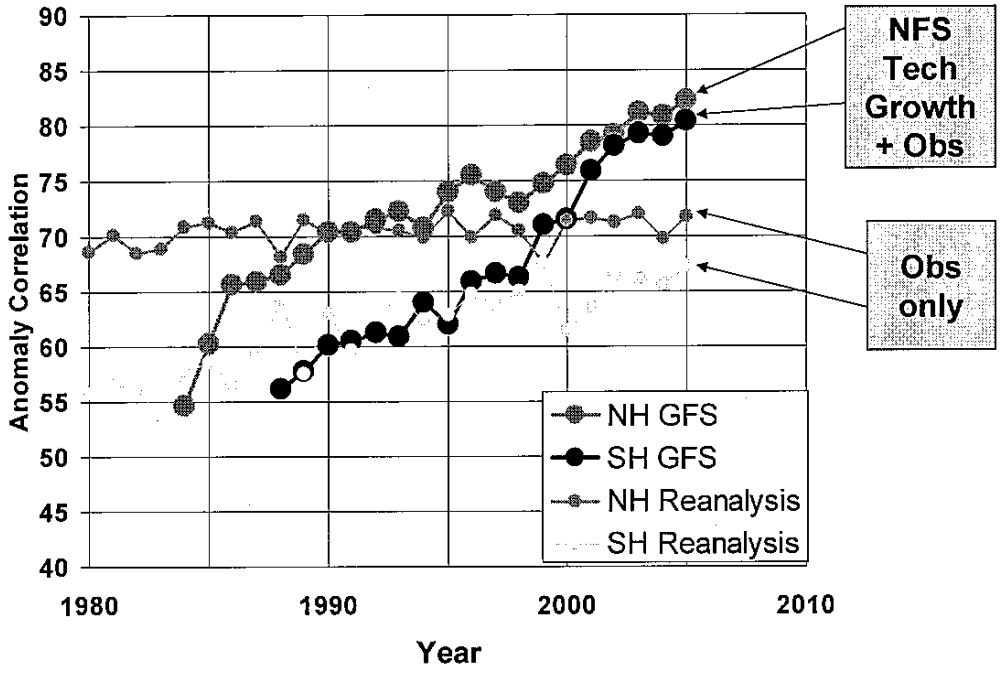
The Environmental Forecast Process



Ingredients for Improved Numerical Forecast Systems

- **Primary ingredients**
  - **Observations**
  - **Data Assimilation & Model technology**
  - **Computing resources**
- **Secondary ingredients**
  - **Post-processing and dissemination**
  - **Research to Operations (R2O) process**

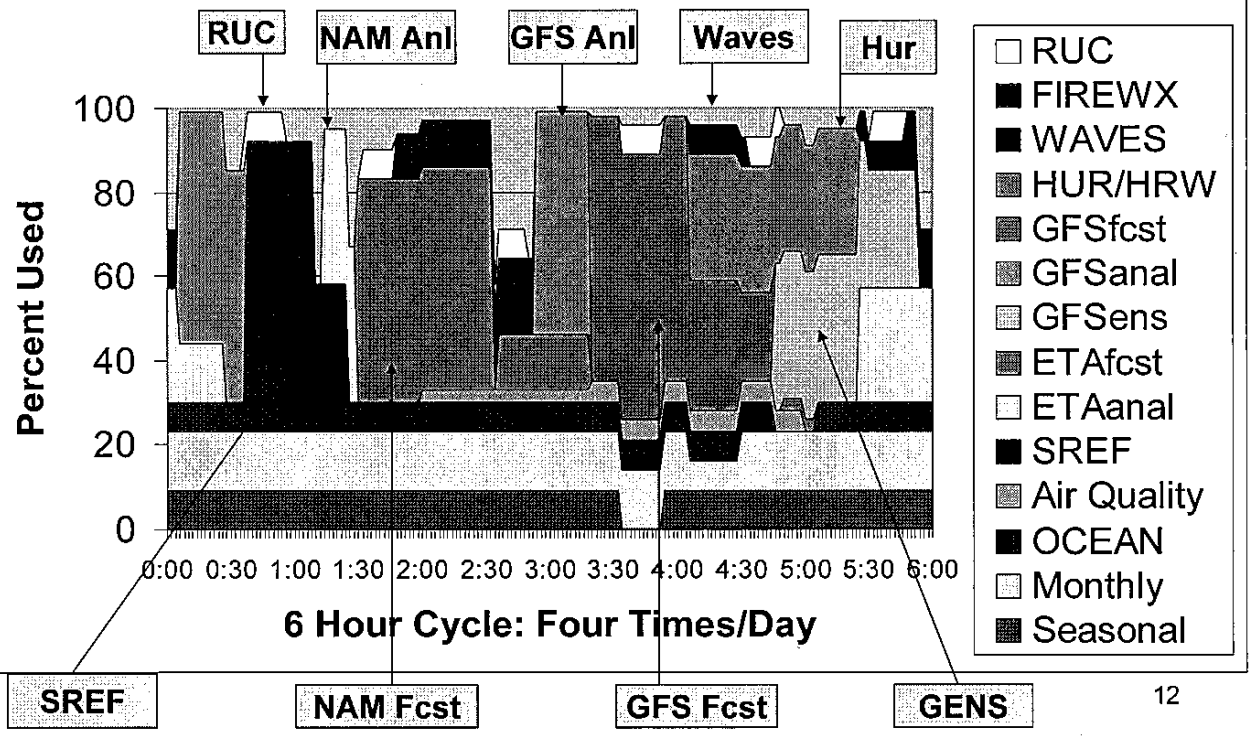
Impact of Observations and Numerical Forecast System Technology Growth on Global Forecasts



NFS Tech Growth:
- Computing
- Data Assim.
- Models
- Ensembles

NCEP Production Suite
Weather, Ocean & Climate Forecast Systems

Version 3.0 April 9, 2004

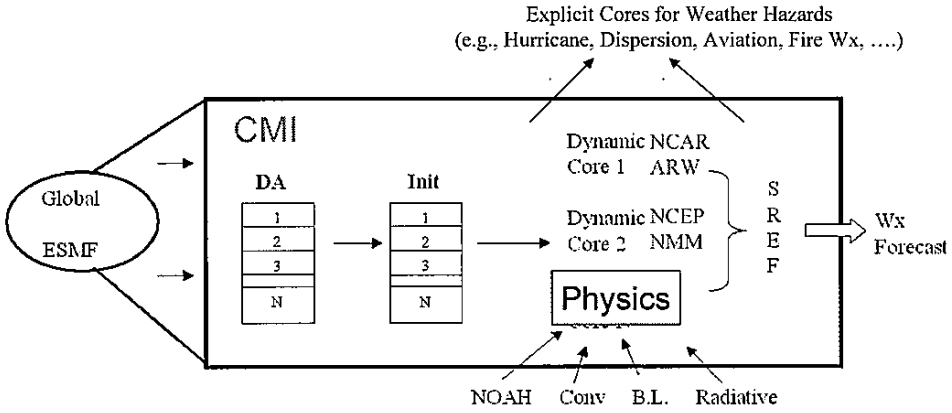


SREF | NAM Fcst | GFS Fcst | GENS

Strategic Highlights

- Mesoscale system consolidation (WRF)
- Next-generation
  - Global forecast model (ESMF)
  - Data assimilation (JCSDA)
- Daily ocean forecasting (HYCOM)
- Hurricanes (HWRF)
- Ensembles (NAEFS, SREF, THORPEX)
- Land surface modeling and hydrology (GAPP)

WRF



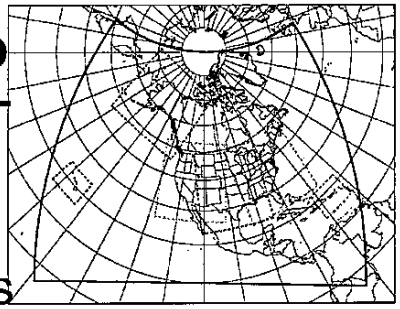
- Mesoscale community model: in development since 1997 – supported through USWRP, NOAA, DOD, FAA, UCAR, NSF
- Supported at Boulder Development Testbed Center (DTC); operational implementation at NCEP and DOD
- Same code run at DTC and NCEP

Implementation Schedule

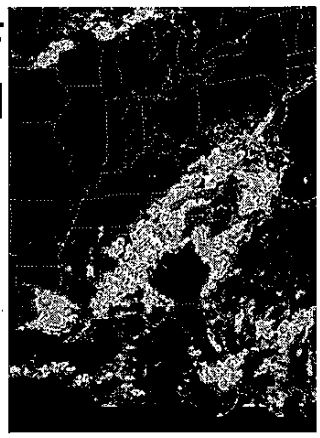
- HiResWindow: WRF Ensemble in FY04 & FY05
- North American WRF: Operational in FY06
- Hurricane WRF: Operational in FY07*
- Rapid Refresh WRF: Operational in FY08*
- WRF SREF : Operational in FY07
- FireWeather/IMET Support and Homeland Security*

* As resources allow

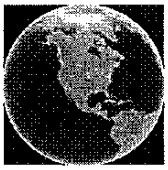
WRF at NCEP



- **21 September 2004**: 8 km WRF ARW & NMM into HiRes Window runs
- **April 2004 to present**: explicit 4.5 km NMM runs for SPC/NSSL Spring Programs
- **28 June 2005**: 5-6 km HiResWindow explicit runs
- **November 2005**: Added 6-member WRF ensemble to SREF (6 = 3 ARW +3 NMM
- **June 2006**: WRF-NMM and WRF-GSI will replace Eta Model and its 3D-Var in North American Mesoscale (NAM) runs

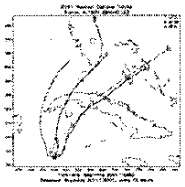


2006 NCEP Production Suite Atmospheric Model Dependencies



GENS

GFDL



G
G
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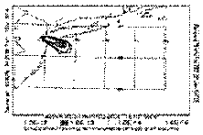
GFS

SREF WRF-NMM WRF-ARW ETA RSM

Dispersion

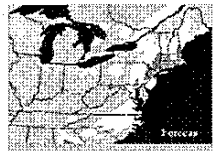


CFS

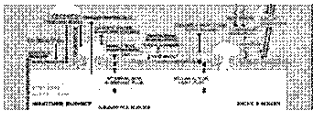
EDAS NAM - Eta

Sev Wx WRF-NMM WRF-ARW

Air Quality

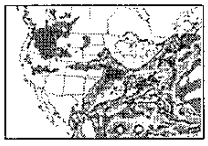


NOAH Land Surface Model

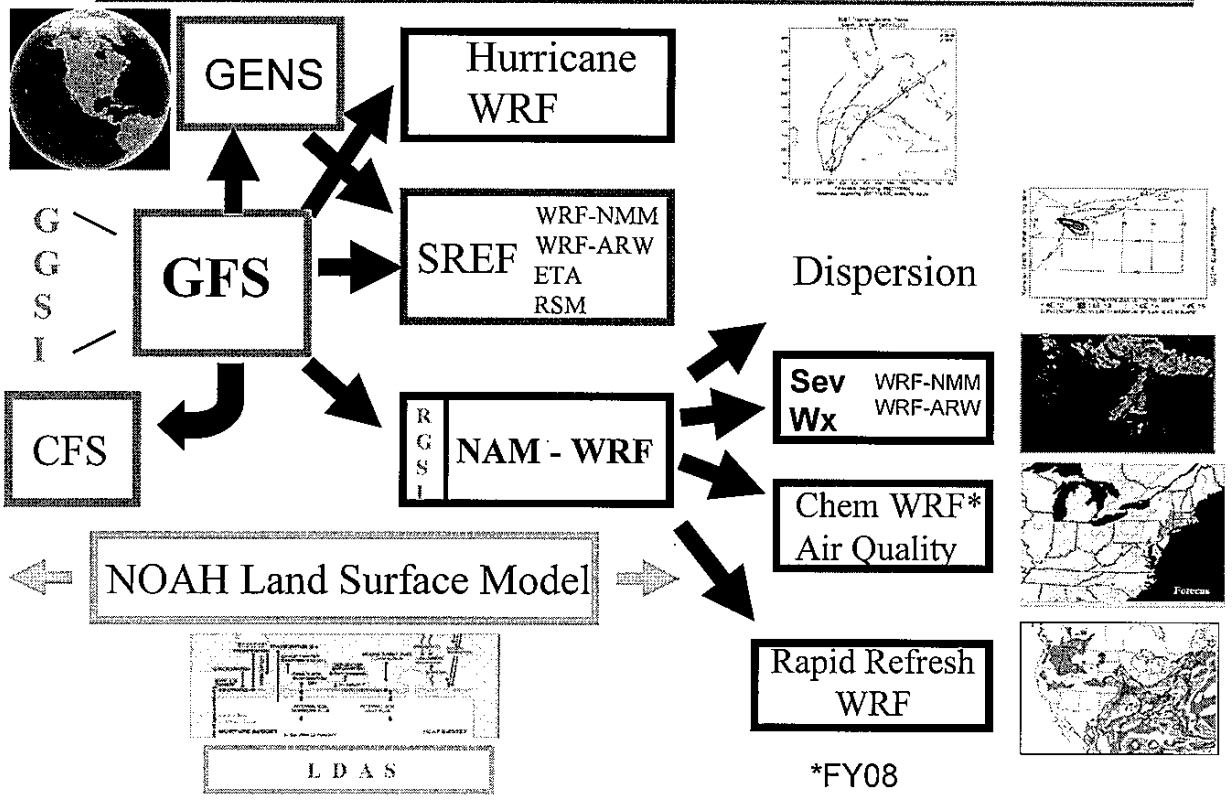


LDAS

RUC



2007 NCEP Production Suite
Atmospheric Model Dependencies



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- Mesoscale system consolidation (WRF)
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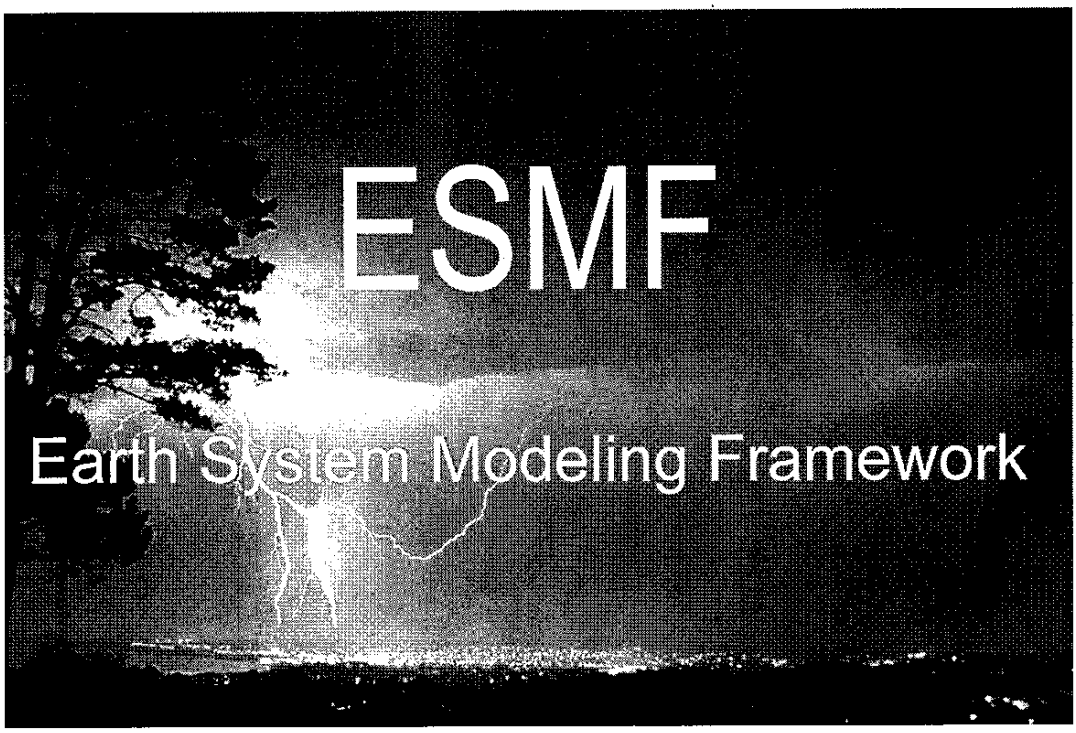
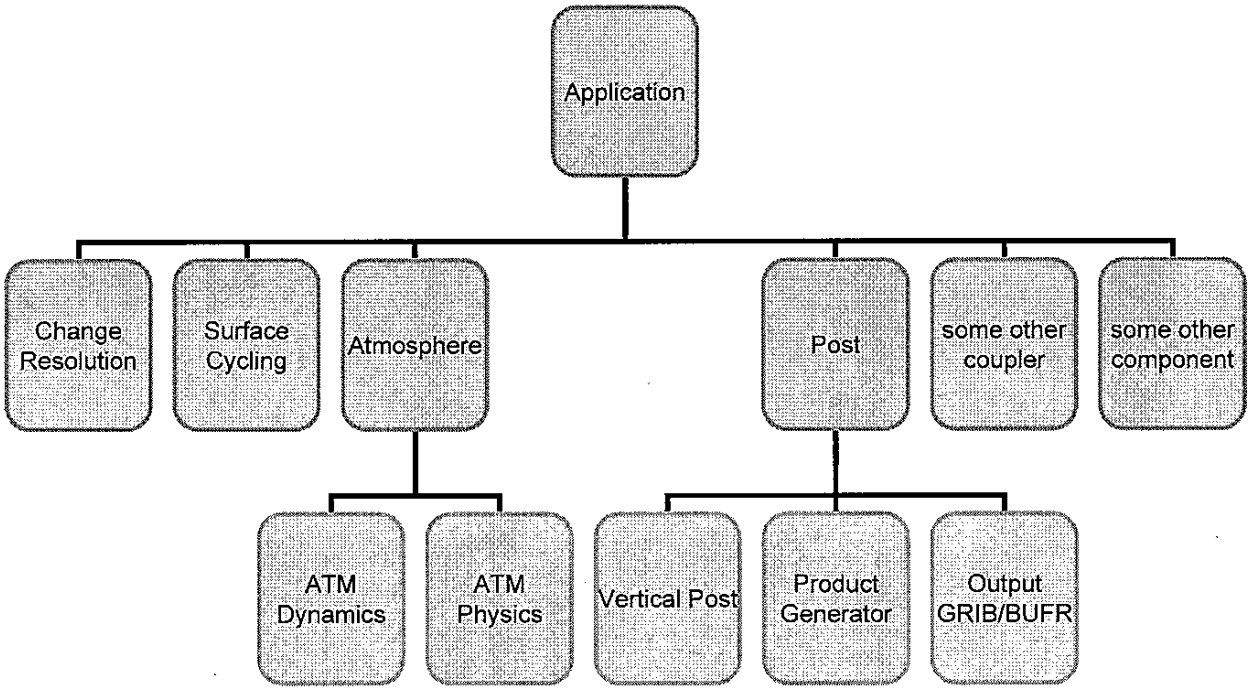
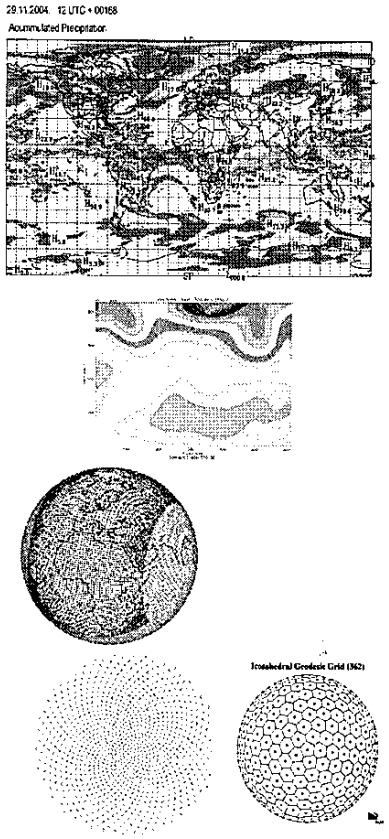


ESMF Component Framework



Next Generation Global Model Development
EMC, ESRL

- Upgrades to current GFS
  - Hybrid sigma-theta vertical coordinate (Juang)
  - Semi-lagrangian advection (Sela)
  - Finite-element vertical discretization (Juang, Kar)
- Upscale NMM to global domain with Lat/Lon grid & Fourier filtering and ESMF compliance
  - Janjic
  - Code keeper (Black)
- Develop Fully Implicit SemiLagrangian (FISL) and SISL techniques within the NMM model structure
  - Kar
  - Janjic
- Apply "baseball" grid to NMM
  - Purser
  - Janjic
- Apply icosahedral and Fibonacci grids to Finite Volume dynamics
  - Purser
  - ESRL staff



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Joint Center for Satellite Data Assimilation

John LeMarshall - Director
Stephen J. Lord (NCEP/EMC)
Jim Yoe (NESDIS/ORA)
L.P. Riishojgaard (NASA/GMAO)
Pat Phoebus (NRL)

NASA-NOAA-DOD Joint Center for Satellite Data Assimilation (JCSDA)

- **NOAA, NASA, DOD partnership**
- **Mission**
  - Accelerate and improve **the quantitative use of** research and operational **satellite data in** weather and climate **prediction models**
    - **Current generation data**
    - **Prepare for next-generation (NPOESS, METOP, research) instruments**
- **Supports applied research**
  - **Partners**
  - **University, Government and Commercial Labs**

Advanced Data Assimilation Strategy and Design Considerations (NCEP/EMC, NESDIS/STAR, NASA/GMAO)

- Common elements promote collaboration and accelerate progress
- Managed diversity provides more information on system performance
- Inclusive development strategy required due to advanced nature of work and **"THE"** answer is unknown
  - EMC: Evolutionary approach through incremental changes → "Simplified" 4-D Var
  - GMAO: Adjoint based techniques → "Classical" 4-D Var similar to ECMWF
  - THORPEX: Revolutionary technique (Ensemble Data Assimilation) different from variational approach
- Disciplined code management is essential for progress

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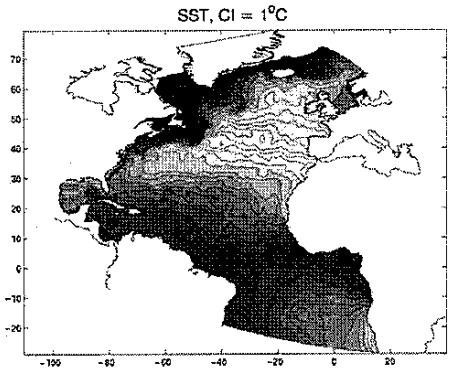
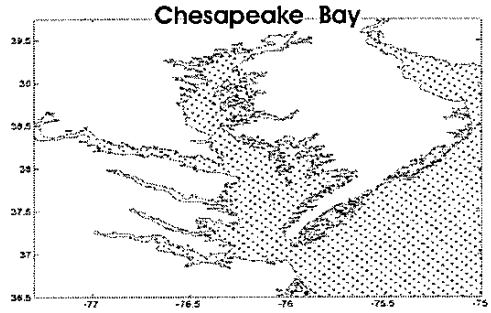
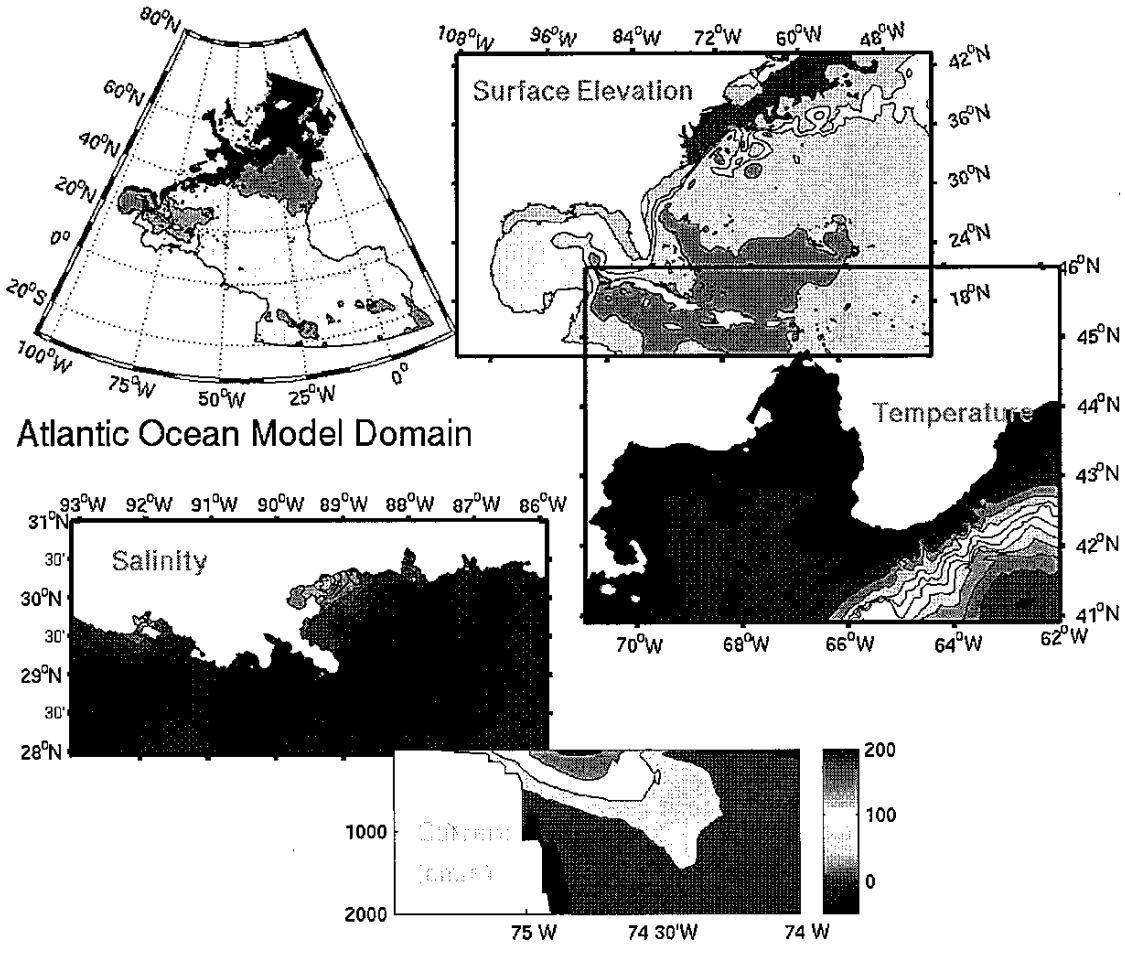
US GODAE: Global Ocean Prediction with HYCOM Operational December 2005

- Goal: to develop and demonstrate real-time, operational, high resolution ocean prediction systems for the Global Oceans and Basins
- NCEP Partners with
  - University of Miami/RSMAS
  - NRL Stennis, NRL Monterey, FNMOC
  - NOAA PMEL, AOML
  - Los Alamos National Laboratory
  - Others (international, commercial)
- Hybrid isopycnal-sigma-pressure ocean model (called Hybrid Coordinate Ocean Model – HYCOM)
- Funded FY 2003-2007 by NOPP







Deployment Schedule

North Atlantic

World Oceans

North-East Pacific

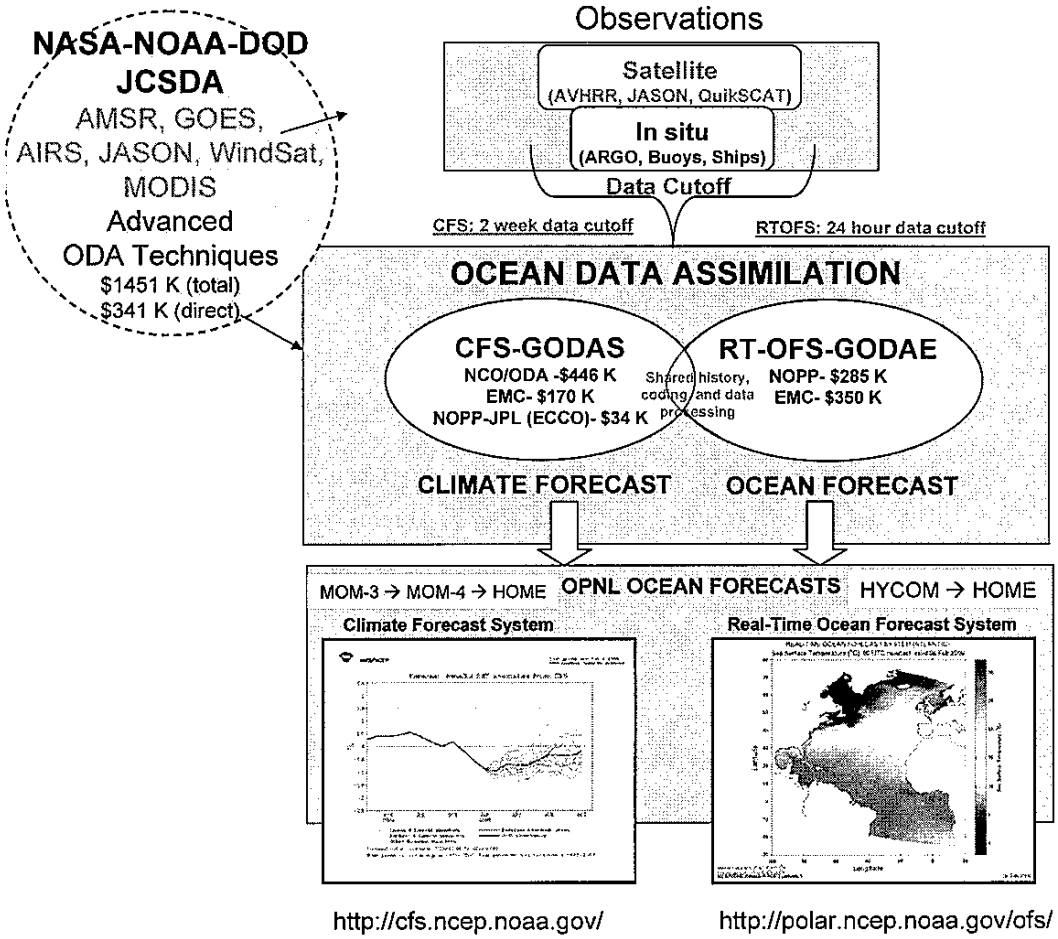
Hawaii

FY 2006 2007 2008

Initiate interactions with NOS on bay and estuary model boundary conditions; Initiate wave-current interactions. Storm Surge Modeling

Global atmosphere-ocean Coupling and Hurricane-Ocean Coupling

29



30

http://cfs.ncep.noaa.gov/ http://polar.ncep.noaa.gov/ofs/

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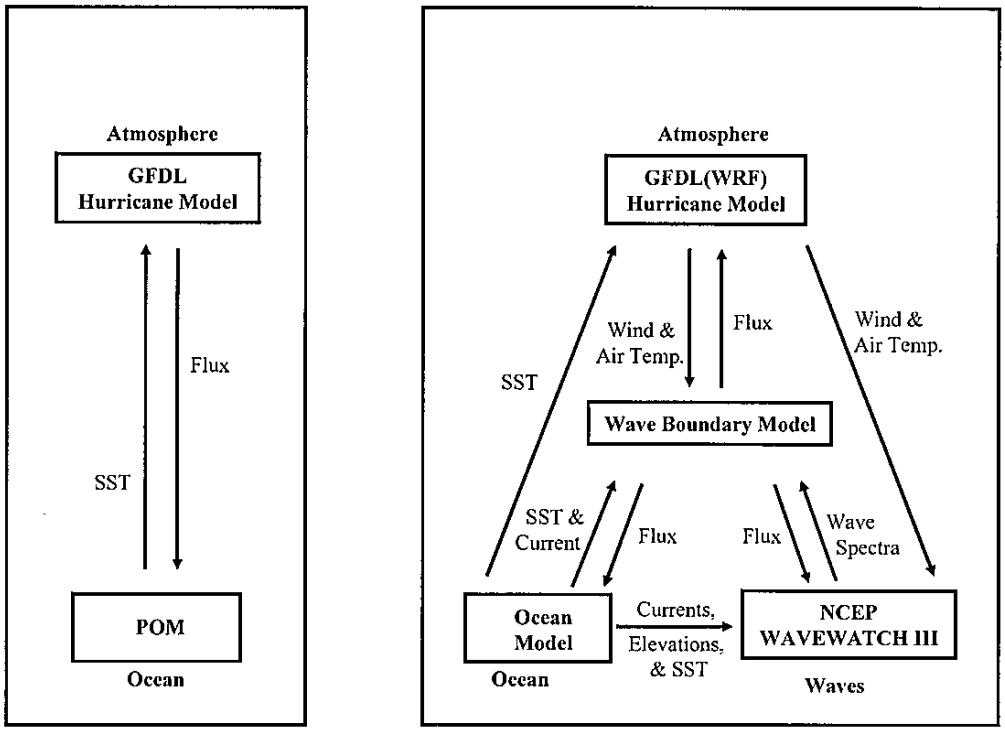
The Hurricane Program

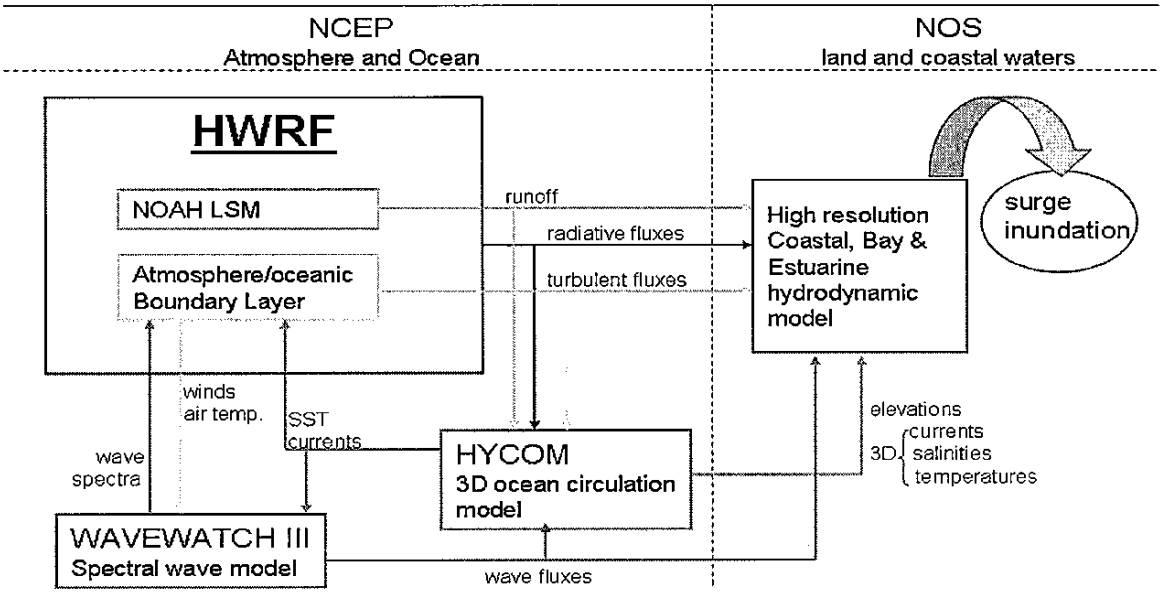
- Highly visible forecasts
  - Protection of life & property
  - Numerical products provide "guidance" for forecasters
  - Extremely competitive
    - Met Office
    - Navy
    - ....
- Global system (GFS) & regional model (GFDL)
  - Annual upgrades
  - Implementation before 1 June of each year
- USWRP support critical for operational system
- Recent beneficiary of supplemental $1 M

Operational GFDL Model **Future Coupled Hurricane-Wave-Ocean Model**



URI & U. Miami partnerships

Hurricane-Wave-Ocean-Surge-Inundation Coupled Models



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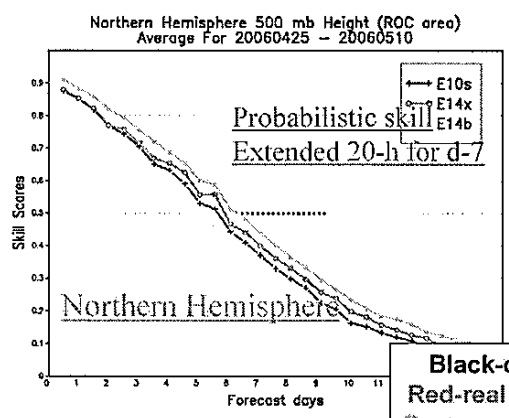
NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS)

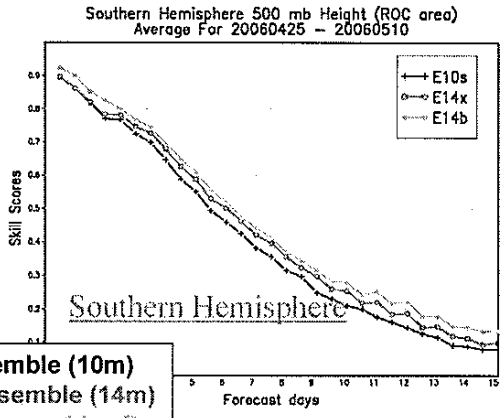
International project to produce operational multi-center ensemble products

- Combines global ensemble forecasts from Canada & USA
  - 40+ members per cycle, 2 cycles per day from MSC & NWS
    - 6-hourly output frequency (instead of current 12-hourly)
    - Replaces current 26 members once a day setup
- Generates products for
  - Intermediate users
    - Weather forecasters at NCEP Service Centers (NWS)
  - Specialized users
    - E.g., hydrologic applications in all three countries
  - End users
    - E.g., forecasts for public distribution in Canada (MSC) and Mexico (NMSM)

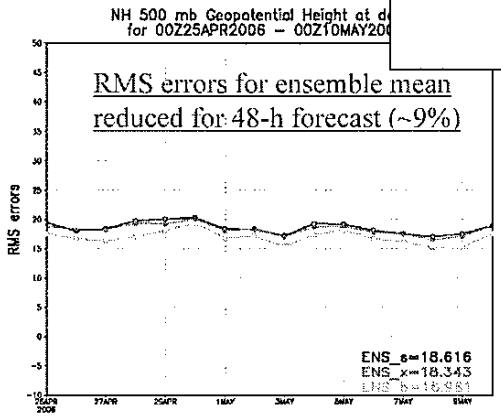
- Prototype ensemble component of THORPEX Global Interactive Forecast System (GIFS)
  - Operational outlet for THORPEX research using THORPEX Interactive Grand Global Ensemble (TIGGE) archive

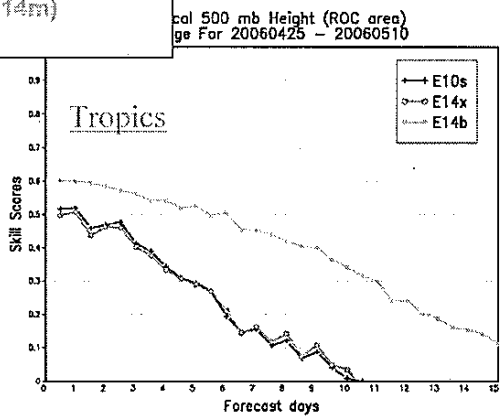
NAEFS Ensemble: Improved Probabilistic Skill





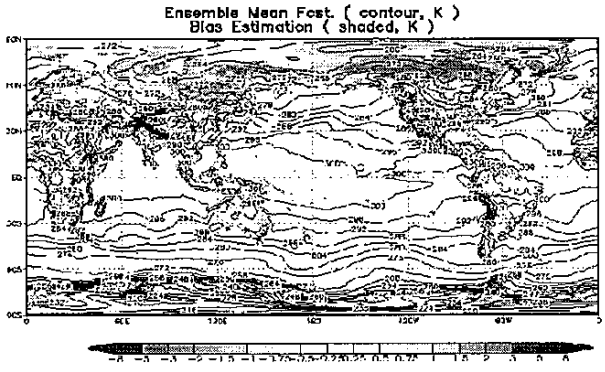
Black-operational ensemble (10m)
Red-real time parallel ensemble (14m)
Green-real time parallel ensemble after bias correction (14m)
16 Cases

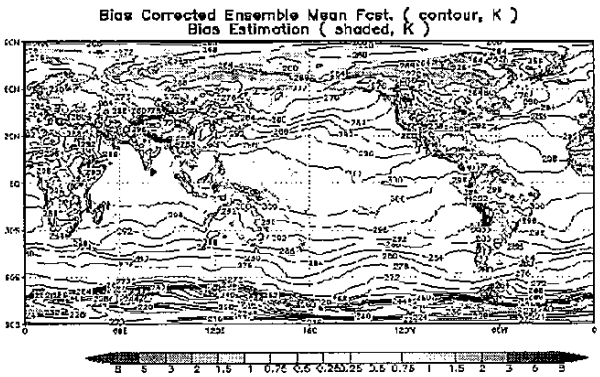


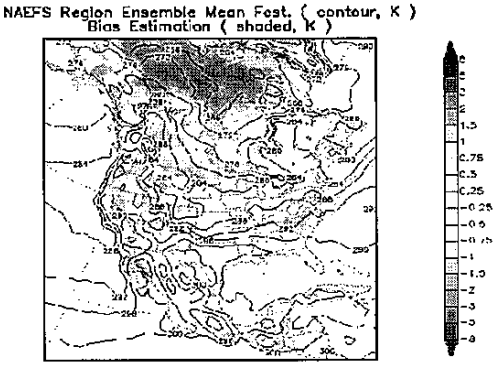


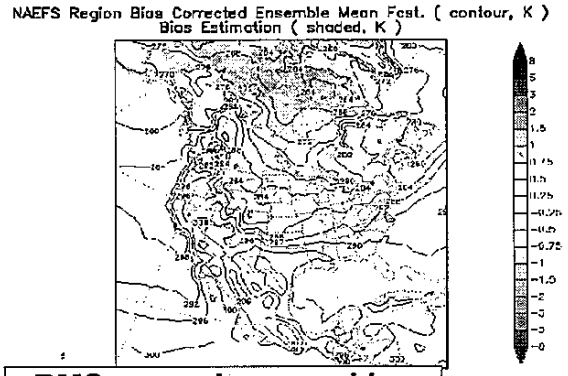
2 meter temperature: **120** hours forecast (ini: 2006043000)

Shaded: left – uncorrected right – after bias correction









Bias reduced approximately 50% at early lead time

RMS errors improved by 9% for d0-d3

NAEFS Performance Review

Appendix 6

KEY PERFORMANCE MEASURES

Improvement in Ensemble Forecasts

Requirement		Threshold	Actual 25Apr-10May06	Variance
Ensemble Mean 3-14 Day Lead Time	Bias Reduction (%)	50%	30-70%	Met or exceeded in Tropics & up to D3 elsewhere; slightly below otherwise
	RMS Error Reduction (%)	10%	Up to 10%	Met up to D3, below expected D4 and beyond
Improvement in Ensemble-based Probabilistic Forecasts	3 Day	6 Hours	12 hrs	Exceeded
	7 Day	12 Hours	16 hrs	Exceeded
	10 – 14 Days	24 Hours	48 hrs	Exceeded

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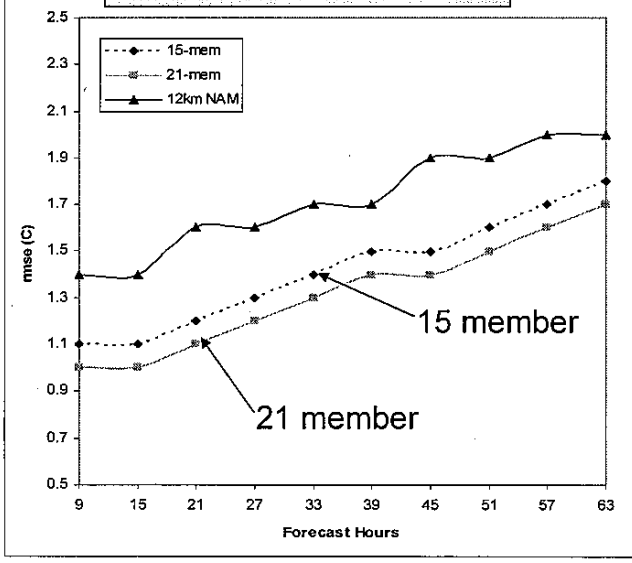
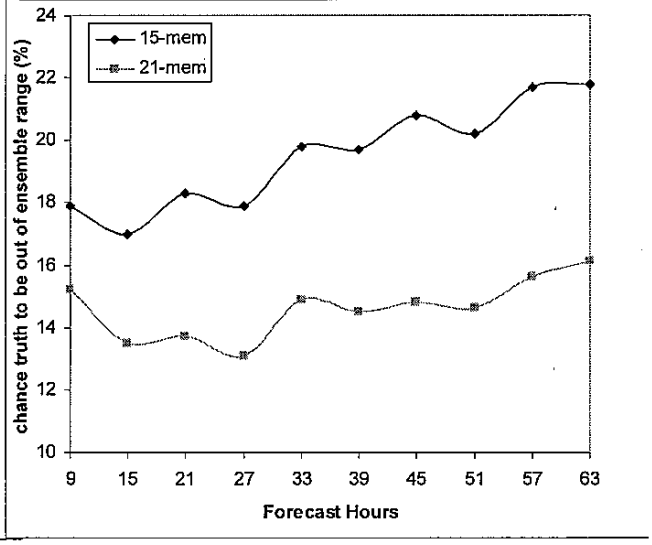
SREF Enhancement with 6 WRF-based Members

RMS Error



Chance that truth is outside ensemble range



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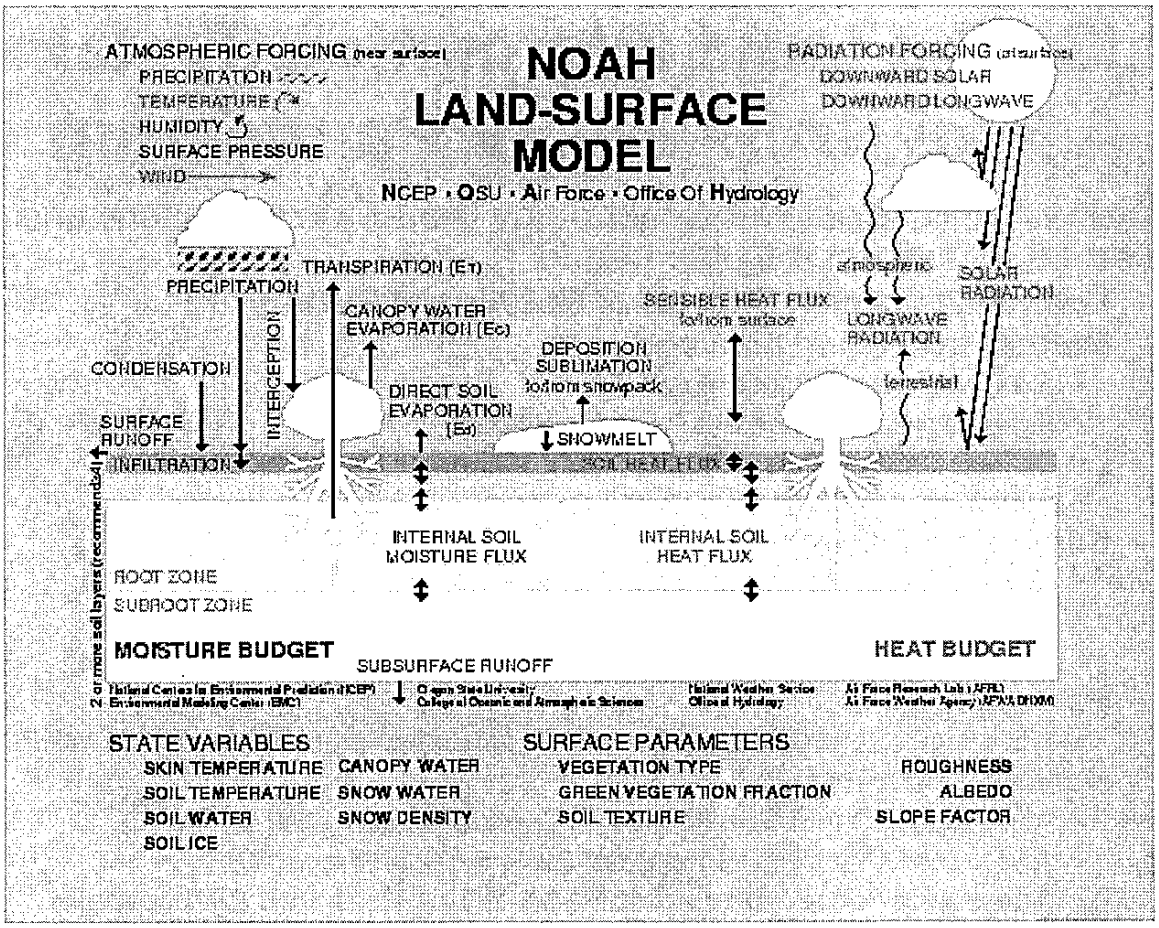
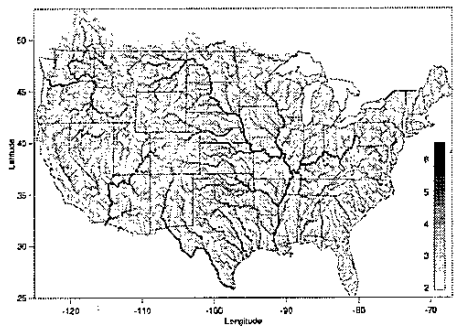
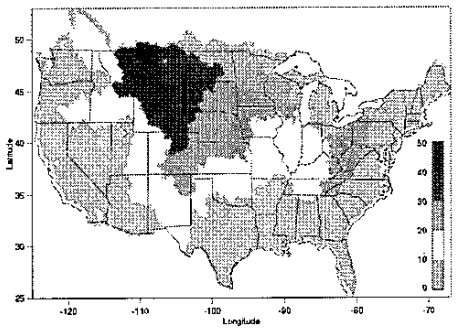


NLDAS Simulated River System

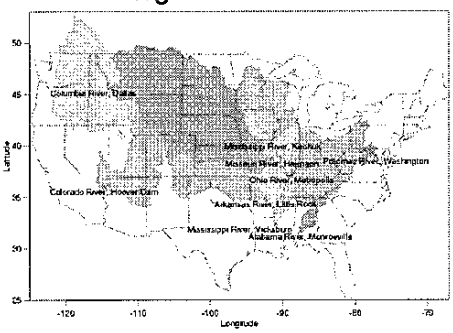
Upstream area [log10(km^2)]



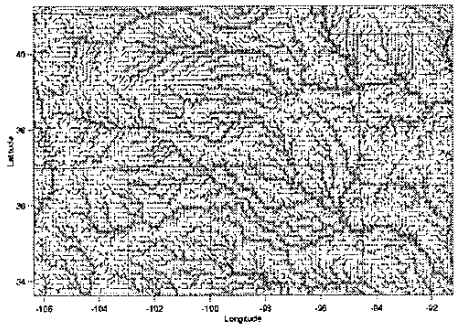
Travel time to outlet [days]



Large River basins



River flow direction mask



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LIS: The Land Information System A joint NASA-NCEP Partnership

- A robust and flexible land/hydrology model infrastructure and testbed to support multiple needs:
  - **Leverages the pilot projects of NLDAS and GLDAS**
  - **Multiple space and time scales**
    - 1-km to 2-deg resolution globally
    - Integrations of a few days to multiple years
    - Multiple land models: Mosaic, Noah, VIC, CLM, Catchment
    - Fast multi-processing computation design
  - **Support multiple programs:**
    - ESMF: Earth System Modeling Framework
    - JCSDA: Joint Center for Satellite Data Assimilation
    - WRF: Weather Research and Forecast Model
  - **Examples:**
    - LIS coupled to WRF model via ESMF for execution of Noah LSM in WRF
  - **Needs/Opportunties**
    - Add JCSDA Community Radiative Transfer Model (CRTM)
    - Add community Kalman Filter data assimilation component
    - **Add stable "core" funding of NASA-NOAA Research & Operations Transition**

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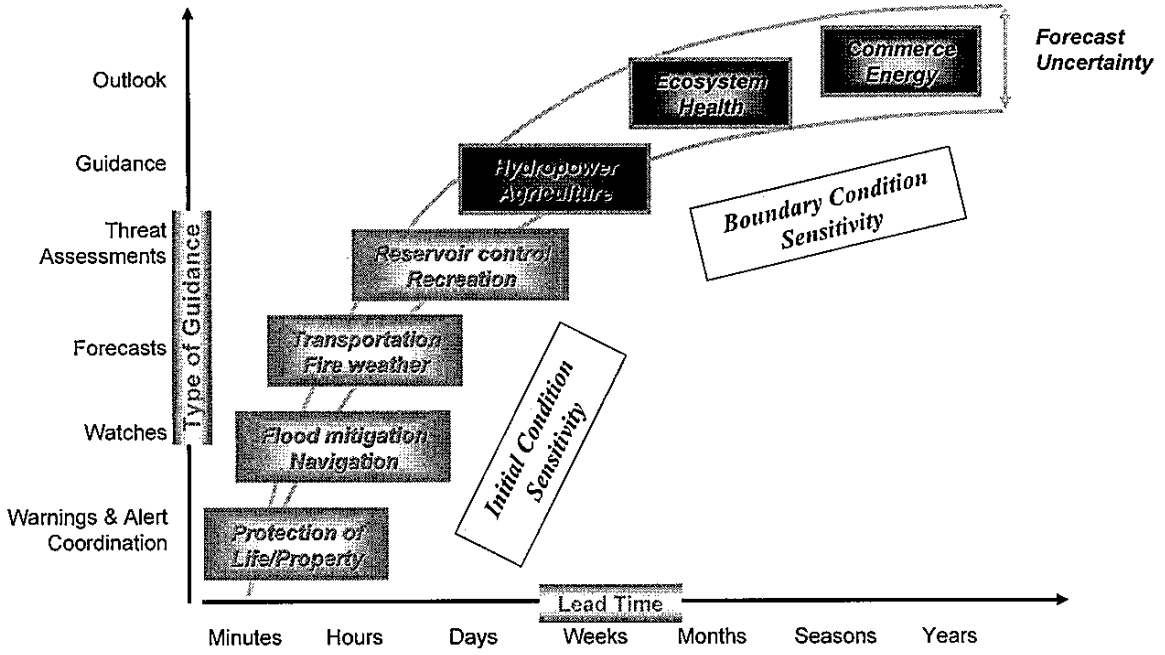
Overview

- EMC organization
- Role of models in the forecast process
- Strategic highlights
  - Mesoscale system consolidation (WRF)
  - Next-generation
    - Global forecast model (ESMF)
    - Data assimilation (JCSDA)
  - Daily ocean forecasting (HYCOM)
  - Hurricanes (HWRF)
  - Ensembles (NAEFS, SREF, THORPEX)
  - Land surface modeling and hydrology (GAPP)
- Proposed strategic plan elements
- Summary

Socio-Economic Benefits of Seamless Weather/Climate Forecast Suite



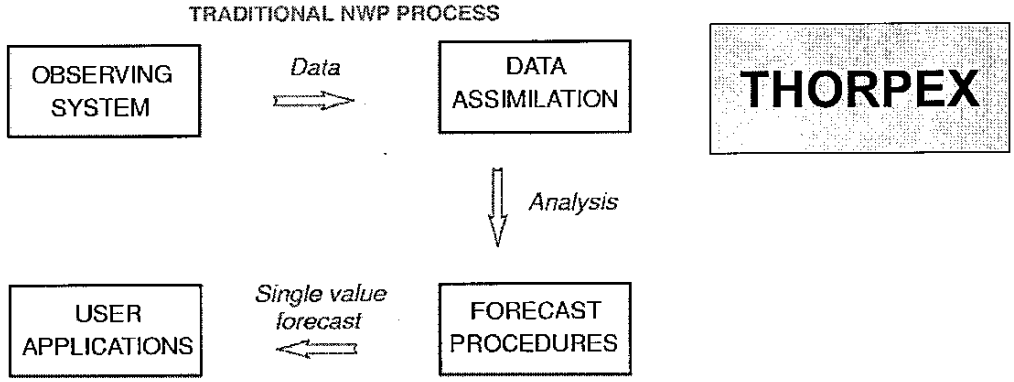


Fig. 2. Schematic diagram illustrating the one-way flow of initial value related information in a traditional NWP forecast process.

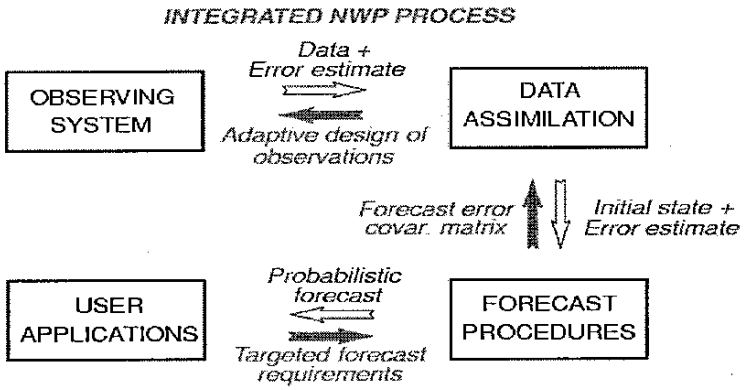


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Fig. 4. Schematic diagram illustrating the two-way flow of initial condition related information in the proposed new, integrated NWP forecast process.

Proposed Strategic Plan Elements

- Improved Services
- Verification and Product Feedback
- Projection Prioritized Seamless Suite
- Information and Dissemination
- Spectrum of Provided Services

Improved Services

- Increased Numerical Forecast System (NFS) capabilities - examples are:
  - AOR for sensible weather
    - Dew Point
    - Maximum Temperature
    - Minimum Temperature
    - Precipitation Amount
    - Probability of Precipitation (POP 12)
    - Significant Wave Height
    - Sky Cover
    - Snow Amount
    - Temperature
    - Weather
    - Wind Direction and Speed
  - Surface transportation
  - Environmental monitoring (AQ + Atmos. Constituents)
  - Ocean (SAR, water levels)
  - Hydrology (water quality)
- Improved forecast accuracy with advanced
  - Observations processing (e.g. quality control)
  - Data assimilation (e.g. advanced techniques)
  - Model accuracy (e.g. dynamics and physics)
  - Post-processing (e.g. bias correction)
- Products characterizing all sources of forecast uncertainty
- More user-relevant products (e.g. radar and satellite view formats)
- Increased use of available observations
- Contributing to observing system design and evaluation for future systems

Verification and Product Feedback

- Verify all products
  - Maintain long term historical data base
    - Demonstrate product improvement
    - Comparison with international and domestic service providers
    - Common methodology across weather, climate, water, ocean, land applications
  - Conduct annual product review
    - Key users participate actively
    - Sets requirements and subsequent actions
    - Provides strategic direction for users (where we are going)

Projection-Prioritized Seamless Suite

- Seamless Suite of Forecast Products
  - Focus depends on forecast projection (e.g. Weather → Climate)
  - Examples are:
    - 0-24 h
      - Severe weather (precipitation, winds, temperature)
      - Sensible weather focus
      - Aviation
      - Surface transportation
      - Hazards
    - 1-3 days
      - Synoptic systems
      - Jet streams
      - Define amplitude of extreme events
      - Oceans (waves, ocean state)
    - 1-5 days
      - Hurricane track & intensity
    - 4-15 days
      - Likelihood of extreme events
      - Regional scale impacts
    - 16-60 days
      - Changes in continental-scale regimes (AO, PNA)
      - MJO and tropical forcing
    - 2-12 months
      - ENSO events
- All applications have a probabilistic component

Information and Dissemination

- "Model of the day" is not a future, scientifically supportable, solution.
- Instead, consider the following maxims:
  - Model output bias-corrected and in terms of climate anomaly
  - Information from all available sources
    - Domestic and international models
  - **Provide maximum usable information from operational NFS with three levels of information**
    - **Most likely forecast**
    - **Description of forecast uncertainty through probability density function (pdf)**
    - **Ensemble-based products for all suites**
  - Disseminate maximum user-relevant information
    - Deliver
      - Both 3-dimensional (horizontal and vertical) fields
      - Pointwise information with time series and vertical sounding capability as appropriate
      - Most likely forecast
      - Description of pdf
    - Make available for user access ("NWS Digital Services")
      - All NFS output including individual ensemble members
      - Ability for user to capture arbitrary collection of 5 dimensional information space (x, y, z, t, variable)
      - Publicly served
        - » User pays for transmission capability
        - » NOAA pays for load-balanced servers and disk farm

Spectrum of Provided Services

- Provide new products and services
  - In response to societal needs
    - Annual review
  - Commensurate with available resources
    - Computing
    - Data assimilation and model personnel and technology
    - Observations
  - Annual strategic presentation to upper NOAA Management
    - Environmental Modeling Program
- Provide training services to enhance product use
  - Annual workshops
  - User guides to products
    - E.g.: use of pdf information
    - E.g.: how "most likely" product is constructed
  - Routinely available verification statistics
  - Product improvements
- Outreach to scientific community
  - Unified Test Bed concept
    - Covers all aspects of NCEP and NOAA product suites
    - Supports transition to operations
    - Sets national guidelines for supporting research
  - NOAA NFS software fully supported to scientific community for all applications (hourly to decadal; atmosphere, ocean, land, hydrology, sea ice)
    - ESMI
- International outreach
  - Support NCEP's NFSs for international use
  - Fully documented systems with training
  - Robust retrieval of boundary condition and initial condition files for local, foreign users
  - Regular user workshops to provide information and discuss problems

Summary

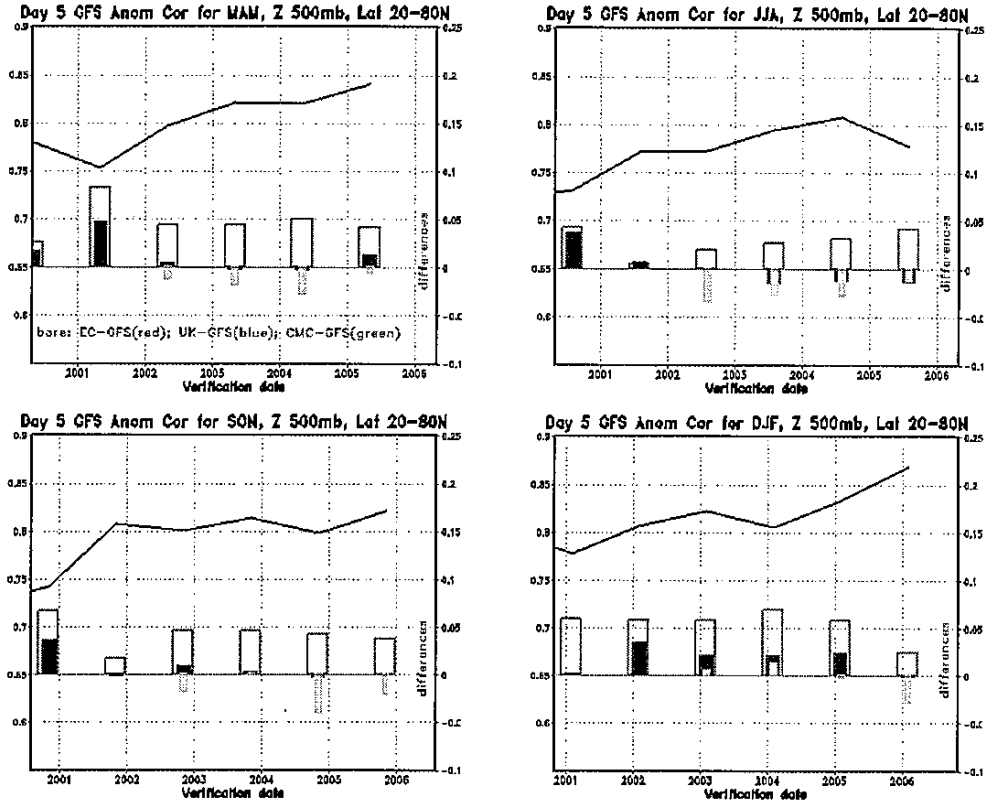
- **WRF**
  - First major foray into community modeling
  - Enables consolidation of mesoscale systems
- **Next-generation global system**
  - Planned to be multi-component system with ESMF glue
  - Data assimilation techniques in collaboration with NASA/GMAO and JCSDA
- **Daily ocean forecasting (HYCOM)**
  - Provides basis for full atmosphere-ocean coupling for weather, including hurricanes
  - Opens door to marine ecosystem forecasting
- **Hurricane WRF**
  - Coupled ocean and waves
  - Already progress on hurricane intensity
- **NCEP systems**
  - Are ensemble based
  - THORPEX is providing ground-breaking studies
- **Land surface modeling and hydrology**
  - Global and domestic hydrological forecasts (drives river runoff for coastal models)
  - Terrestrial ecosystem (e.g. dynamic vegetation) impacts
- Proposed strategic plan is aligned with NWS CONOPS

Backup

Overview

- EMC Organization
- Performance of Global System for Weather & Climate
- Strategic highlights
  - Mesoscale system consolidation (WRF)
  - Next-generation
    - Global forecast model (ESMF)
    - Data assimilation (JCSDA)
  - Daily Ocean Forecasting (HYCOM)
  - Hurricane Forecasting (HWRF)
  - Ensembles (NAEFS, SREF, THORPEX)
  - Land Surface Modeling & Data Assimilation (GAPP)
- Strategic plan elements
- Summary

Performance Comparison



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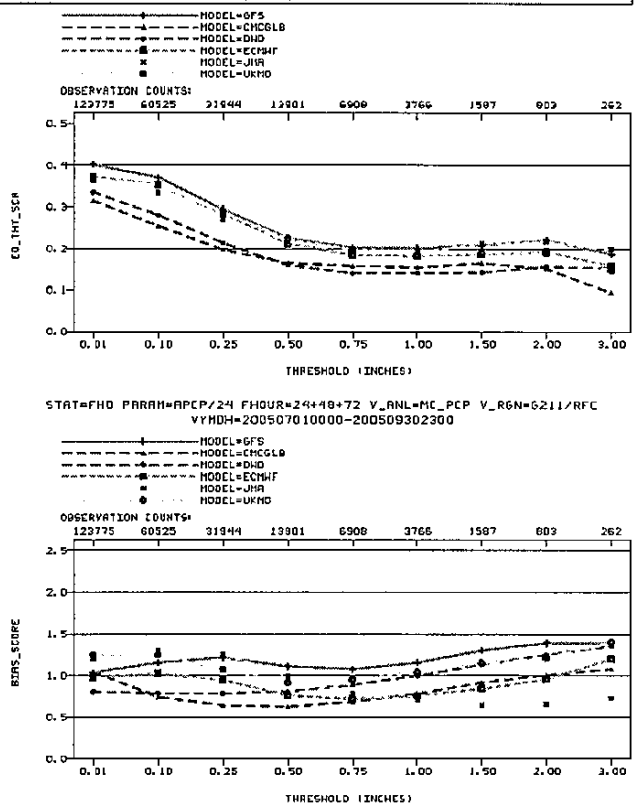
Global Models
1 July 2005 – 30 September 2005
24 – 72 h Forecasts



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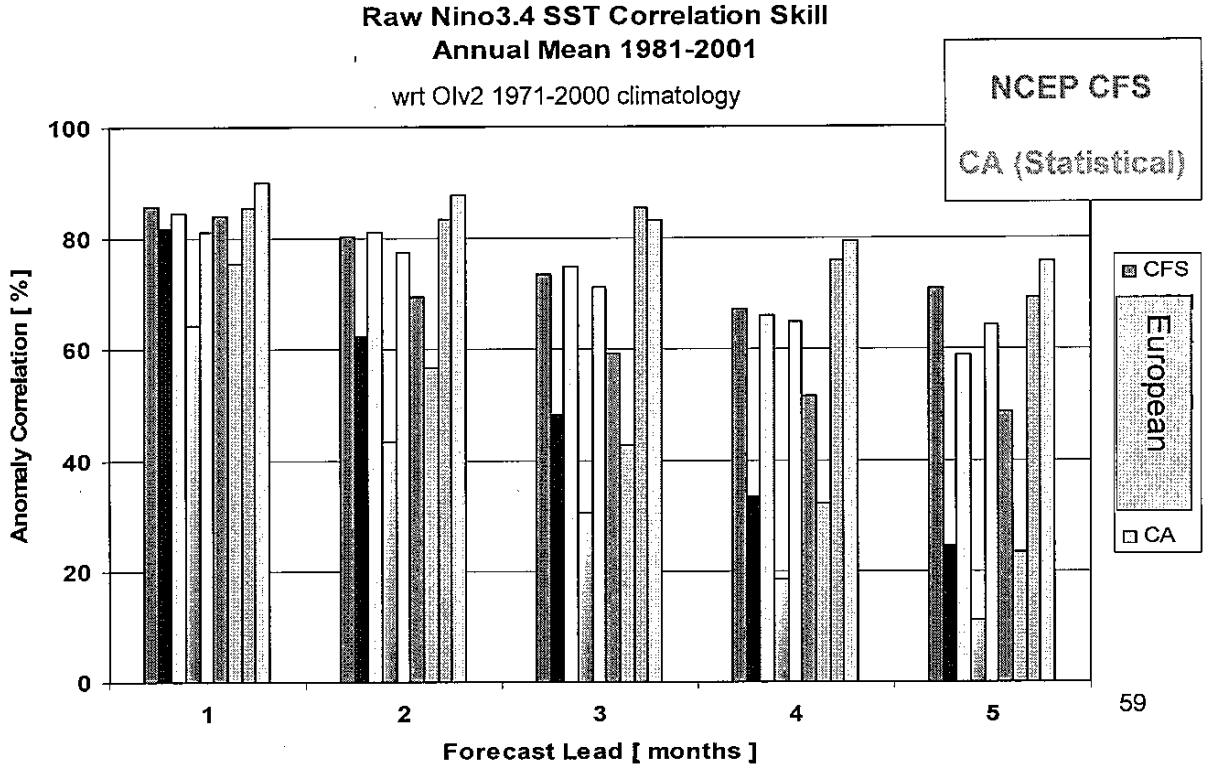
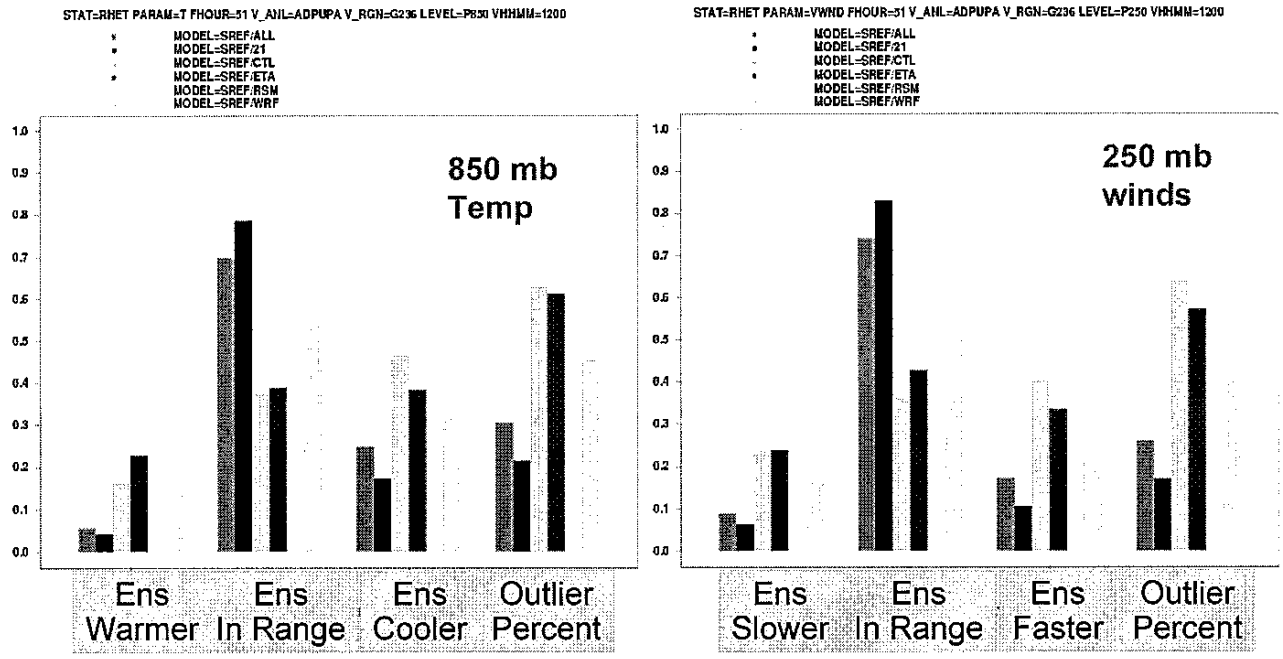
NCEP Performance Comparison
Seasonal Forecasts



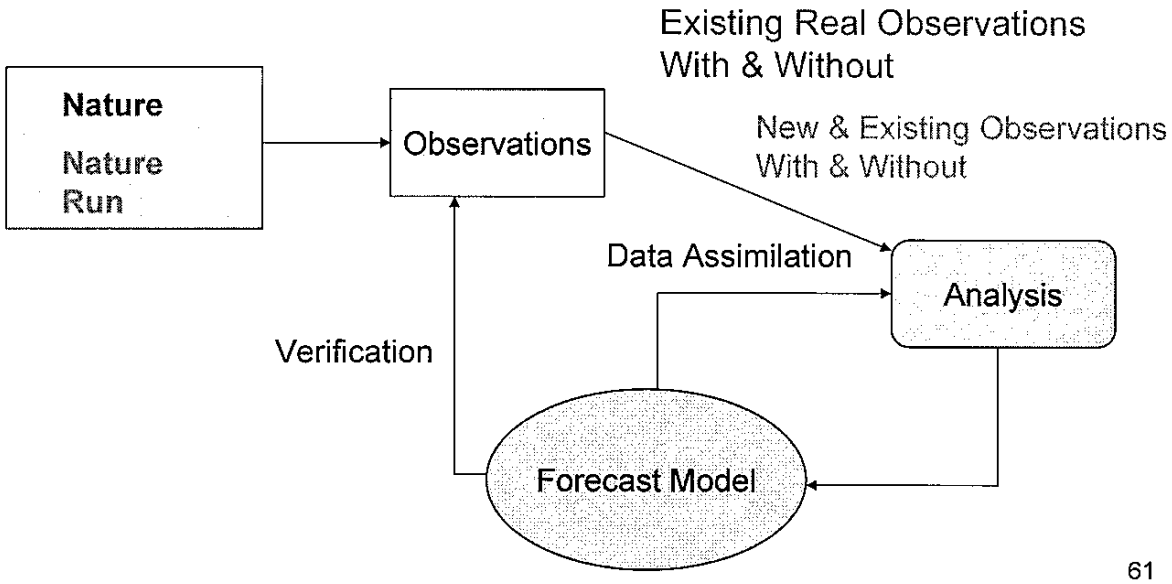
SREF Operational Performance

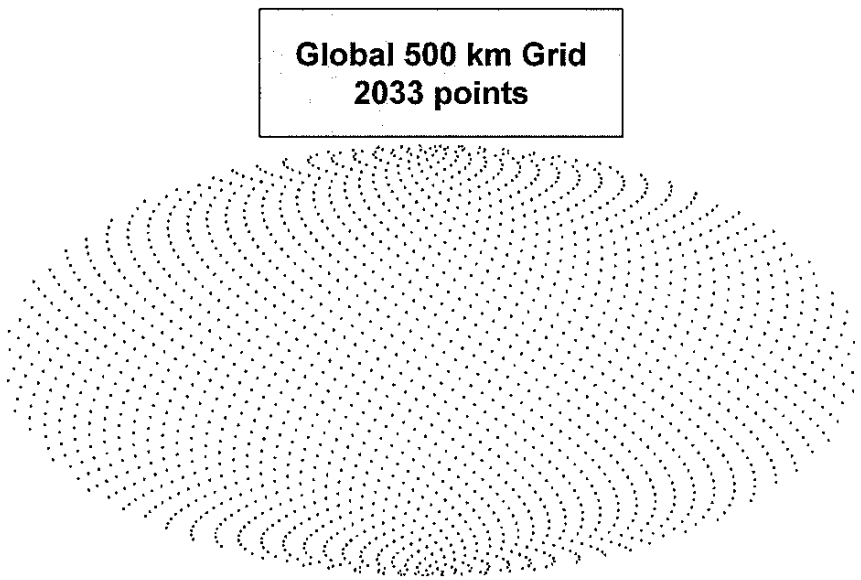


- ***Outlier percentage reduced for SREF/21 system***
- ***WRF sub-members agree best w/ obs as compared to Eta and RSM sub-members***

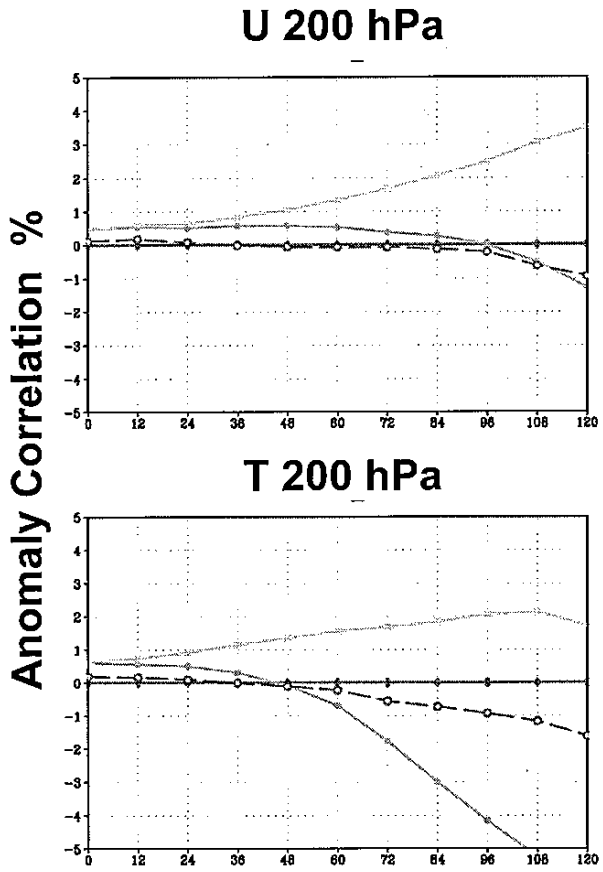
Introduction to OSSEs
Basic Concepts

- Real/OSSE Data Assimilation System





Fibonacci Grid used in the uniform data coverage OSSE



N. Hem. Forecast Skill
Upper Tropospheric Wind & Temp.
Global Rawinsondes
Compared to Today's Obs.

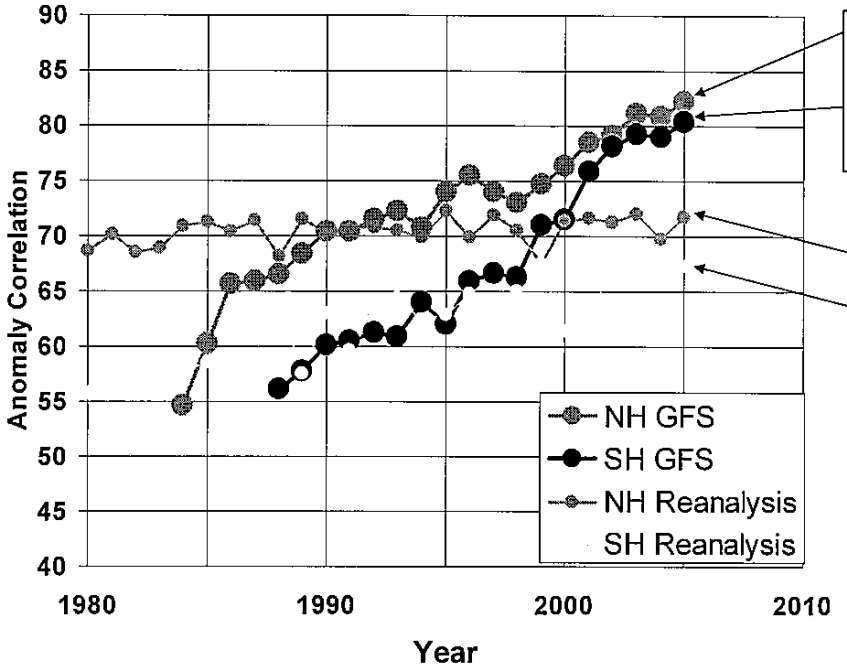
- **Control**
  Conv + TOVS
  (today's obs.)
  T62 model
- **500 km raobs**
  T62 model
- **1000 km raobs**
  T62 model
- **500 km raobs**
  T170 model

Computing Comparisons

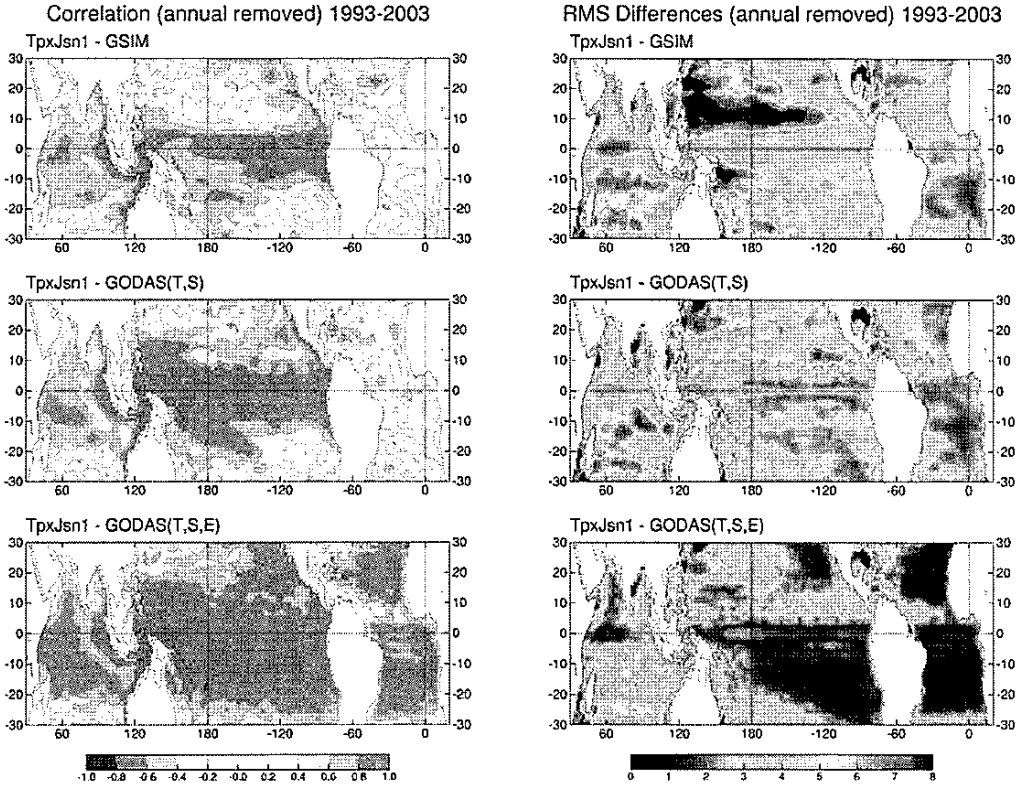
International Operational Weather & Climate Forecast Centers 2006-2007

Center MP=Massively Parallel	Peak Power (TF)	Throughput (TF)
NCEP (IBM, MP)	16	1.0
UKMET (NEC, vector)	4	1.5
ECMWF (IBM, MP)	36.5	2.2
China (IBM, MP)	21	1.3
Korea (Cray, vector)	18	5.4
Japan (Hitachi, vector)	21.5	7.2

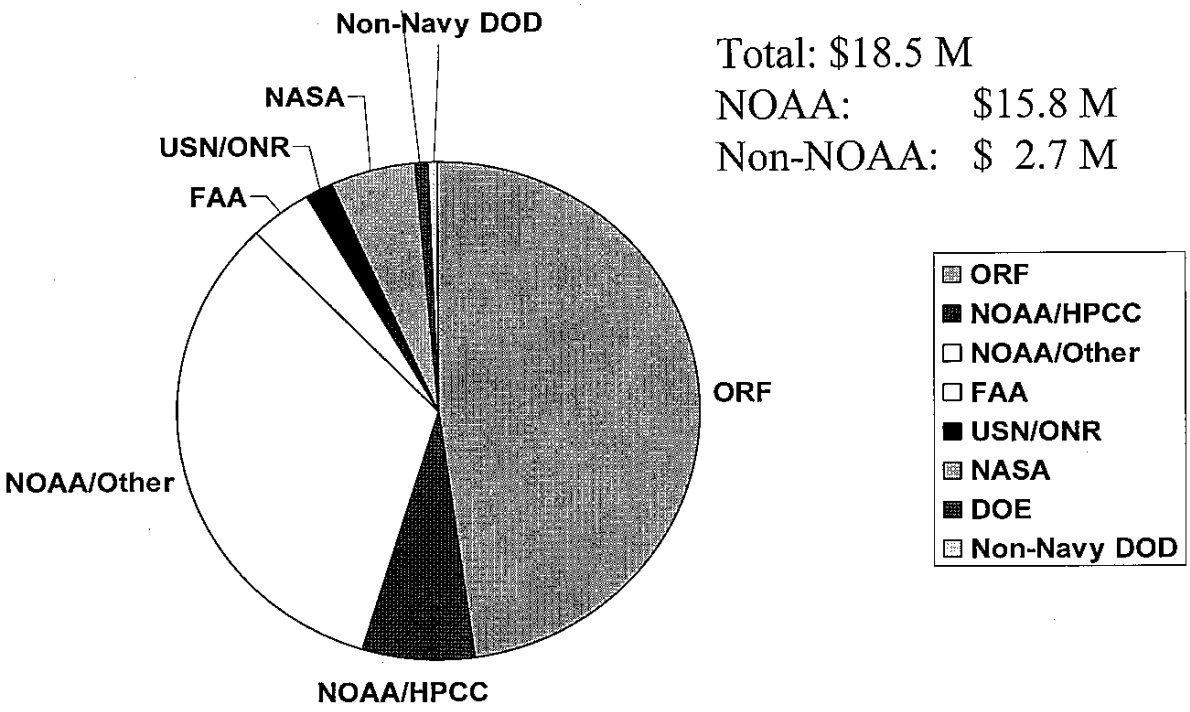
Impact of Observations and Numerical Forecast System Technology Growth on Global Forecasts



NFS Tech Growth:
Computing
Data Assim.
Models
Ensembles

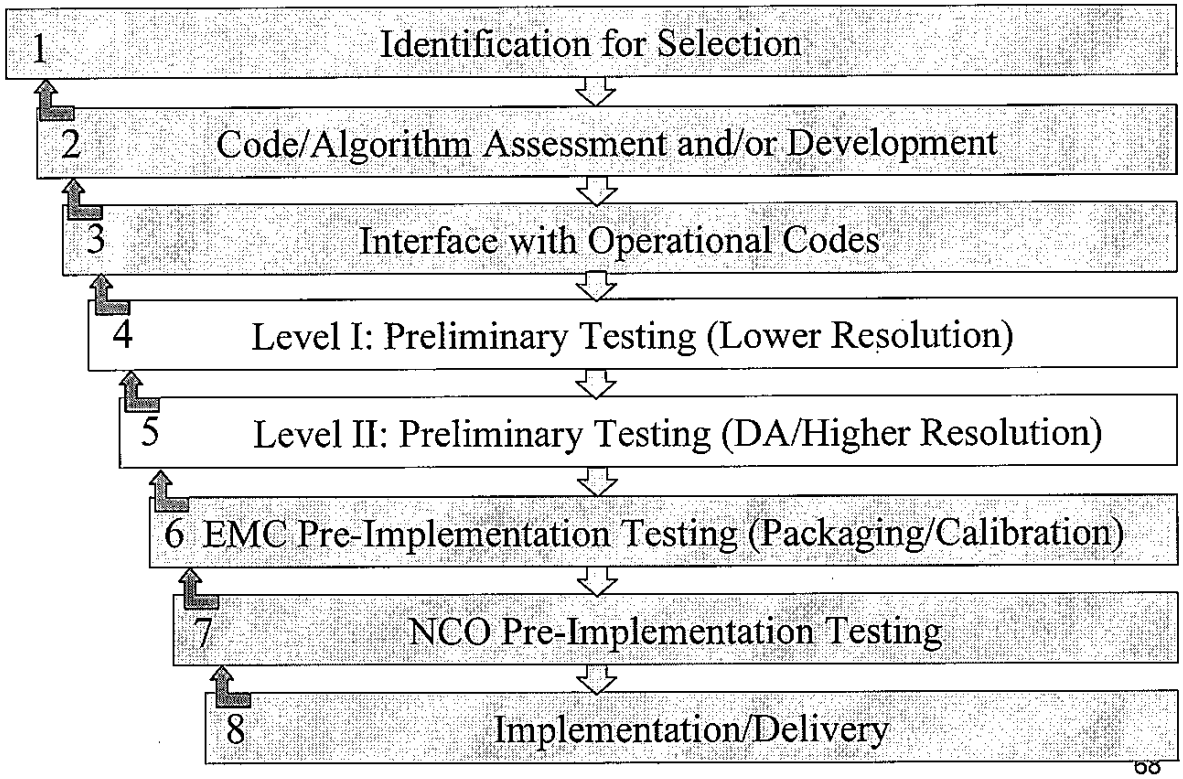


FY06 EMC Budget



Kelly report (2000) recommendation: 75% ORF, 25% "soft"
2002 budget supplement and adjustment: $2.8 M; 2006 DA: $1.0 M

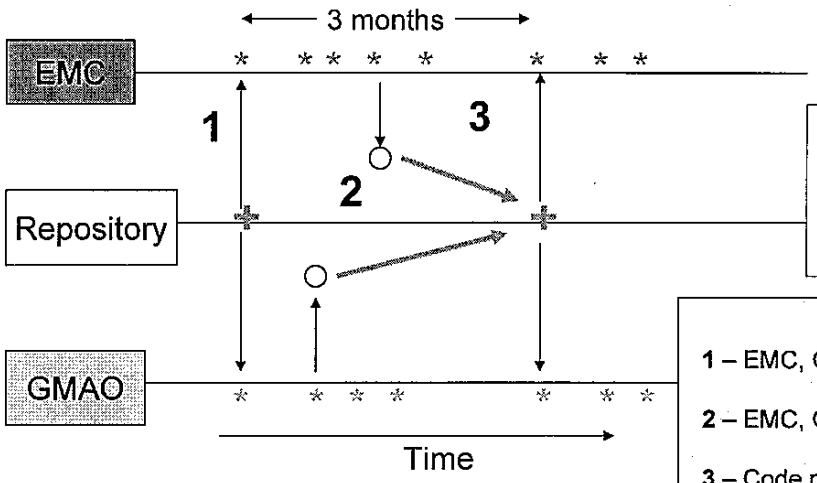
Transition Steps (Modeling)



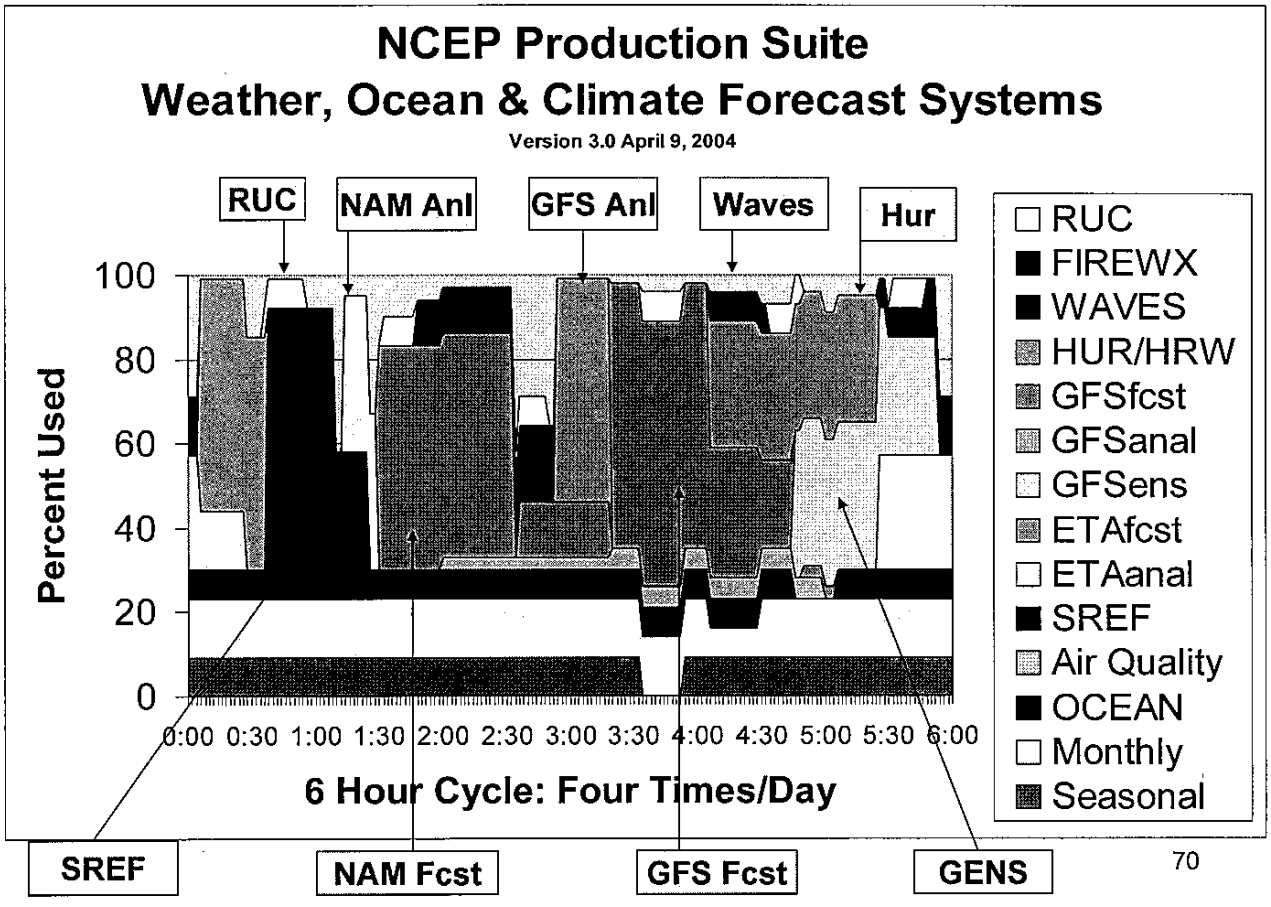
EMC-GMAO-STAR Code Management for Atmospheric Data Assimilation

Process: similar to ECMWF & Météo-France who have annual code mergers
But, to promote collaboration, EMC and GMAO **use same repository** and mergers are more frequent (**3 months**)

GSI & CRTM supported



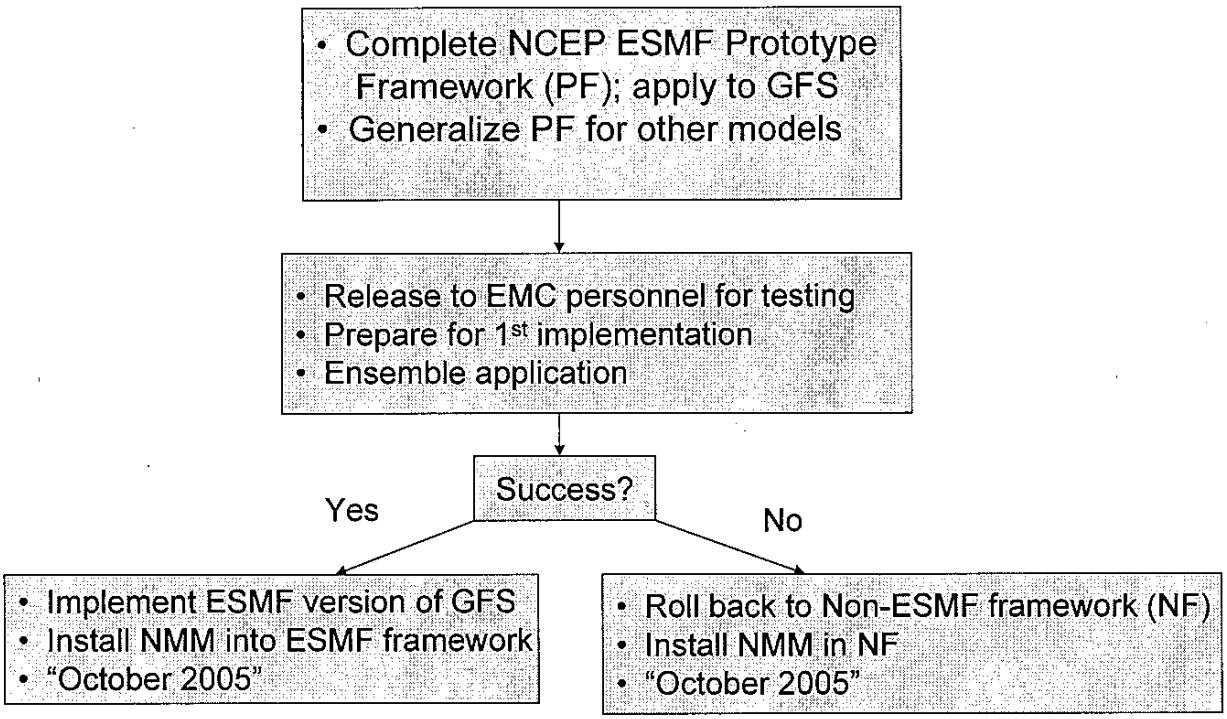
Protocols
1 – EMC, GMAO take (agreed-upon) merged code from repository to begin work
2 – EMC, GMAO incorporate developments into repository
3 – Code mergers, repository changes and timing are NCEP's decision



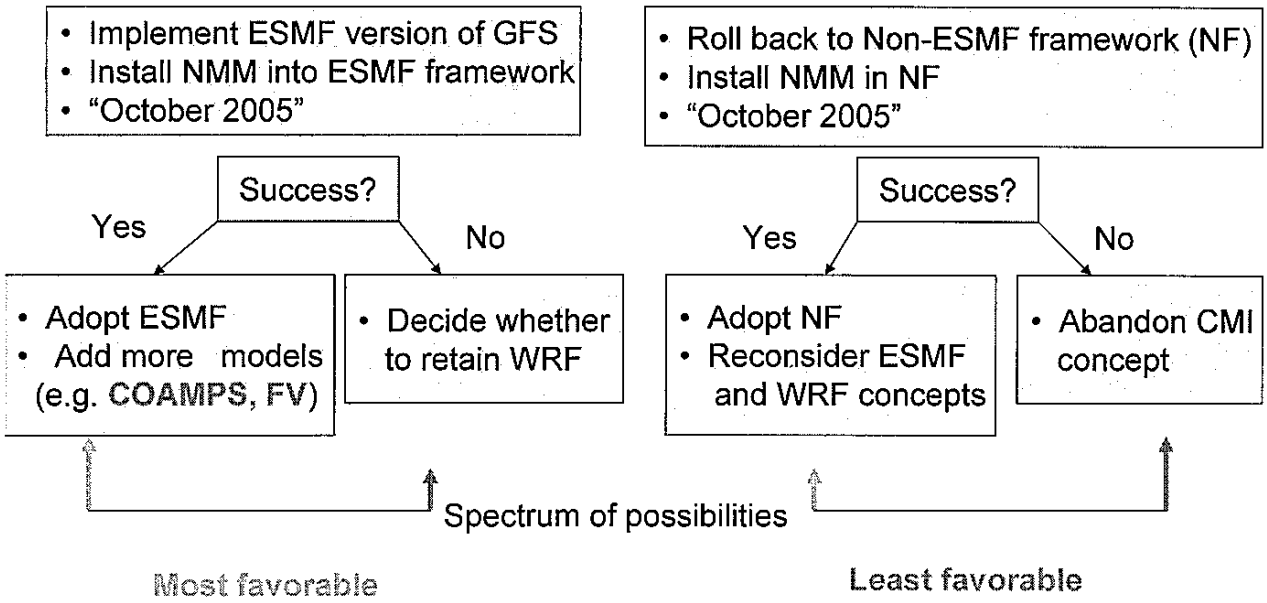
Data Assimilation Status (cont)

- Gridpoint Statistical Analysis (GSI)
  - NCEP's next generation system
    - Evolutionary combination of the global SSI analysis system and the regional ETA 3DVAR
    - Application to both global and regional analysis
    - Strong heritage to satellite, radar, profiler, surface data
  - Background error defined in grid space instead of spectral space
    - Allows use of situation dependent background errors
    - Will accept ensemble information
  - Improved balance condition
    - Adiabatic dynamics model
    - Capable of simplified 4-D Var
  - Improved and modernized code
    - F90/95 structures and utilities
    - Increased scalability of code
    - Efficiency
      - Redesigned data distribution
      - Some OpenMP
    - Better documentation
    - Less dependency on IBM
  - Community support intended but not resourced
    - Currently 15 registered groups (46 users) using GSI code
    - NASA/GMAO major group using code and to date they have provided the most updates from external users

EMC Plan for Moving Forward



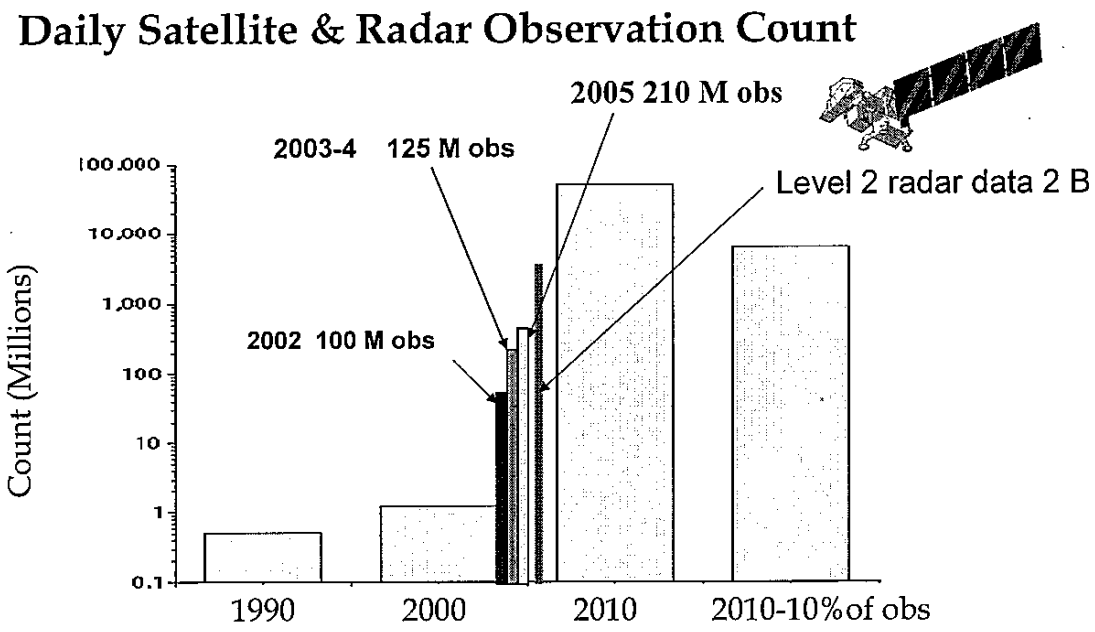
EMC Plan for Moving Forward (cont)



Proposed NOAA Earth Modeling System Infrastructure

- Provide NOAA and external users access and support for operational and research ESM software components
  - Support NOAA Test Beds
  - Contributions from model groups
- Establish NOAA standards
  - ESMF compliant components
  - Data formats (GRIB, BUFS, NetCFS, converters)
- Supported categories
  - Observations
  - Model-enabling databases (e.g. topography, land-sea mask)
  - Forecast models
    - Atmosphere
    - Ocean
    - Wave
    - Storm surge
    - Sea ice
    - Land surface
    - Ecosystem
    - Stream flow
    - Air chamistry
    - Space weather
  - Data assimilation
  - Post processing and product generation
  - Verification
  - Utilities
    - Format converters
    - Basic scripts
  - Limited diagnostic packages
  - Case archive

NPOESS Era Data Volume



Five Order of Magnitude Increase in Satellite Data Over Next Ten Years

Strategy and Design Considerations (cont)

- Common elements
  - Analysis code
    - Gridpoint Statistical Interpolation (GSI)
    - Observations treatment
      - Formats
      - Available information from each obs. Source
    - Diagnostics, including Analysis Adjoint system
  - ESMF compliant components
    - Analysis
    - Model Dynamics
    - Model Physics
  - Testing protocols and case loads
- Managed diversity through different model components
  - Provides additional diagnostic information
  - NCEP uses Global Forecast System (GFS) Spectral Model
  - GMAO uses Finite Volume (FV) dynamics with physics components different from NCEP

Current Satellite Data Assimilation Development

- **JCSDA partnership for Community Radiative Transfer Model (CRTM)**
  - **NESDIS/ORA** leads scientific development
  - **EMC** transitions development to operations & maintains operational codes
  - **GMAO** focuses on applications to NASA instruments used in research DA systems
  - Examples of CTRM applications
    - **AIRS**
    - **MODIS**
    - **WindSat**
    - **SSM/IS**
    - **AMSR**
    - **OMI**
    - **ATMS**
    - **IASI**
    - **CrIS**
    - **OMPS**
- **JCSDA partnership for COSMIC** (results next slide)
  - Project management (**NESDIS**)
  - Data delivery, formatting (**UCAR, NCEP** Central Ops)
  - Scientific algorithms and QC (**JCSDA, NESDIS, UCAR**)
  - Testing with CHAMP data prior to launch with DA system (**JCSDA, EMC, UCAR**)

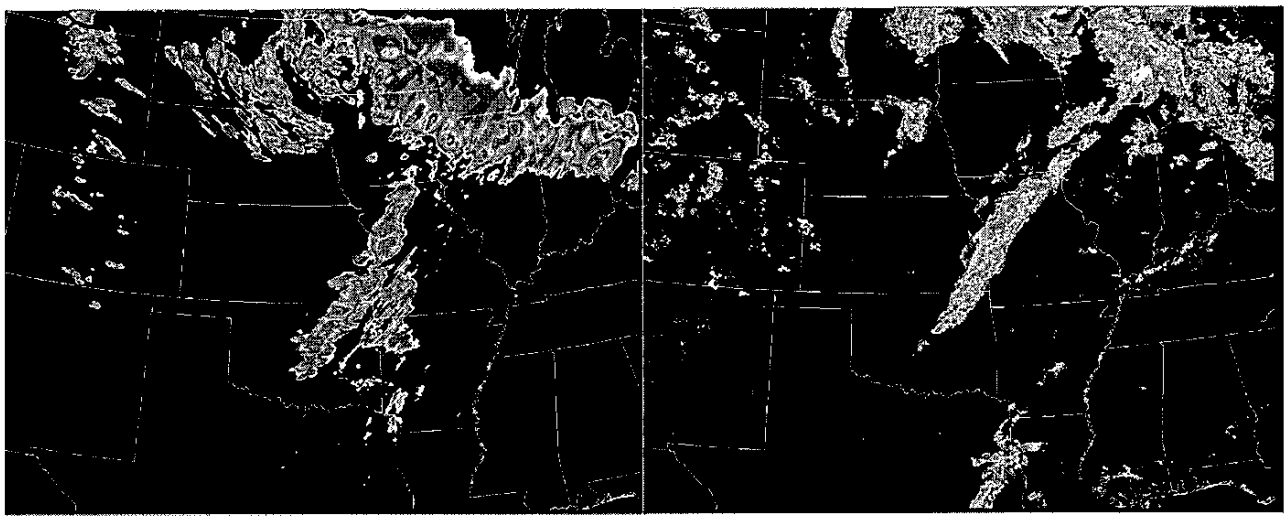
Current Satellite Data Assimilation Development (cont)

- **Improved use of satellite data for SST analysis**
  - Improved AVHRR QC and bias correction (Xu Li, A. Harris)
  - Addition of simplified ocean mixed-layer model (EMC-MMAB, GMAO)
  - Use of microwave instruments (e.g. AMSR-E)
- **Upgrades to ozone assimilation**
  - GOME and current NASA, NOAA instruments (CPC, JSDI; Stajner, GMAO, AO)
- **Land surface data assimilation**
  - Use of GMAO Catchment model as multi-Land Surface Model (LSM) system (together with Noah, VIC and Sacramento LSMs)
  - Collaboration on advanced Ensemble Kalman Filter (EKF) techniques
- **Ocean data assimilation**
  - Use of altimeter data (EMC, Behringer)
  - Impacts on S/I forecasting (EMC, Behringer)
  - GMAO uses Poseidon isopycnal model but will test developments in MOM-4
- **Observing system design and impacts**
  - Analysis adjoint diagnostic tools
  - Observing System Simulation Experiments (OSSEs) for
    - Understanding interaction between observing system and DA system
    - Defining potential impact of and preparing for future instruments

Example of Explicit 4.5 km WRF-NMM

courtesy of Jack Kain

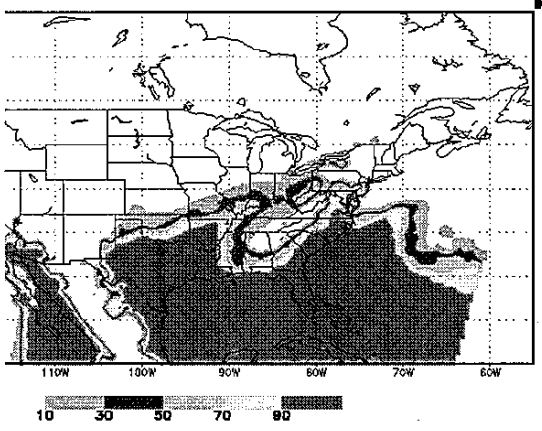
WRF 24 hour 4.5 km forecast of 1 hour accumulated precipitation valid at 00Z April 21, 2004 (better than 12 hour forecasts by operational models)



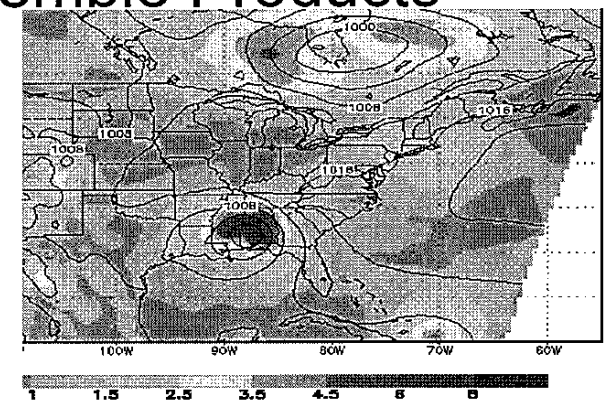
4.5 km WRF-NMM

Verifying 2 km radar reflectivity[79]

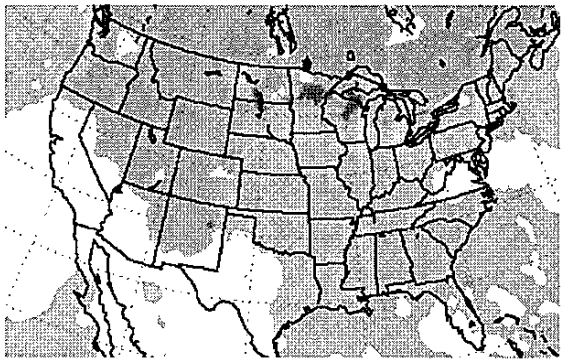
Ensemble Products



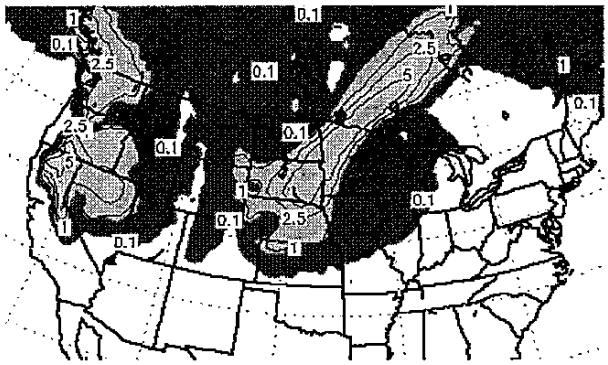
Prob. THI>75



Mean/Spread Surface Pressure



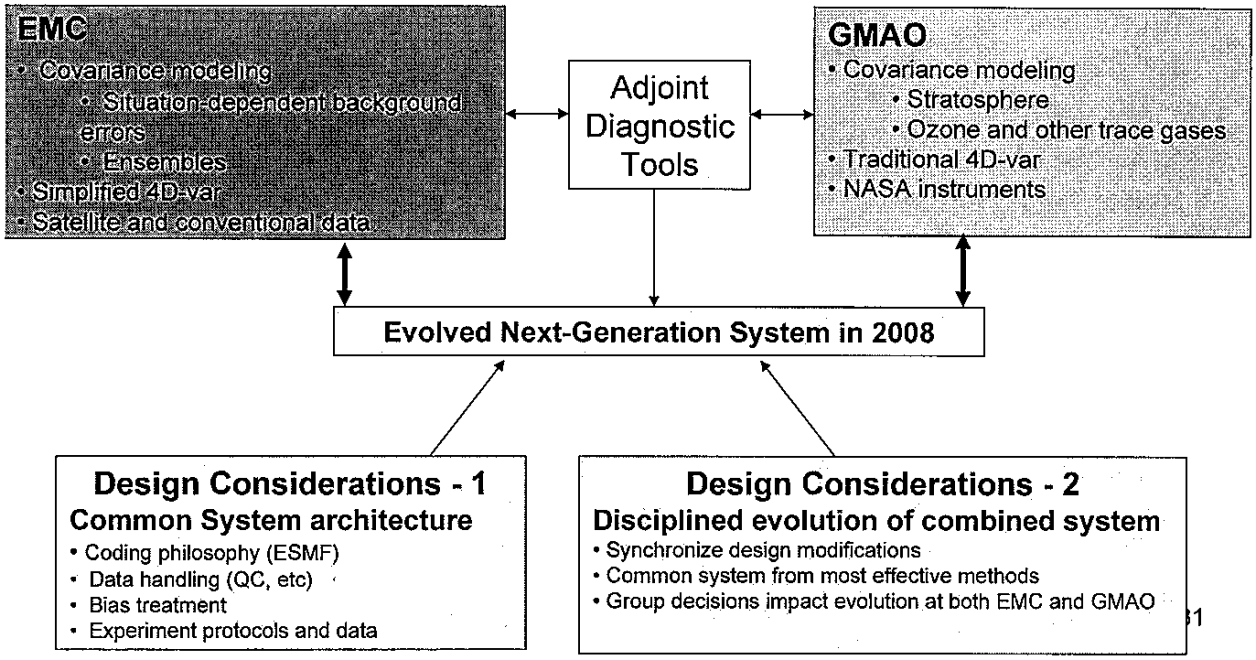
Dominant Precip Type



Mean/Spread 24 h snowfall

EMC-GMAO
Advanced DA Development (Var)

Complementary Development Focus and Common Architecture



Advanced DA Techniques - Plans

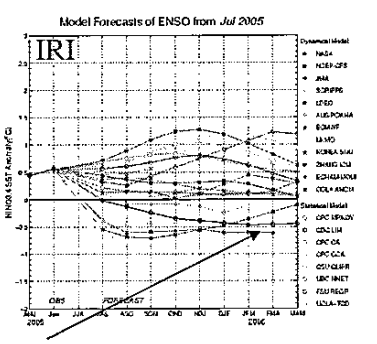
- **Short Term Plan (0-3 years)**
  - Converge EMC and GMAO development to common analysis code (DONE)
  - Harness NESDIS/STAR(ORA) expertise for Community Radiative Transfer Model (CRTM) (DONE)
  - ESMF compliant system for major components (analysis, CRTM, model)
  - Fully coordinated software evolution with **managed system diversity**
  - Applications to **both** global and regional systems (NCEP requirement)

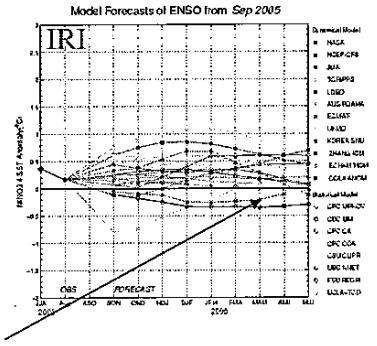
- **Long-Term Plan (>3 years)**
  - Implement next generation operational DA system at
    - NCEP for operations
    - NASA for research
  - Prepare for assimilation of
    - NPP instruments (ATMS, CrIS, OMPS, VIIRS)
    - Full NPOESS era suite
  - Continue focus on advanced NASA instruments for R-2-O transition
  - Expand applications beyond atmosphere to
    - Ocean
    - Land surface
    - Global environmental monitoring and Air Quality
      - Ozone
      - Aerosols
      - Trace gases

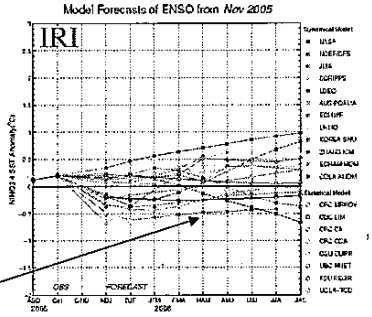
Summary of CFS Forecasts for 2005-2006 La Nina

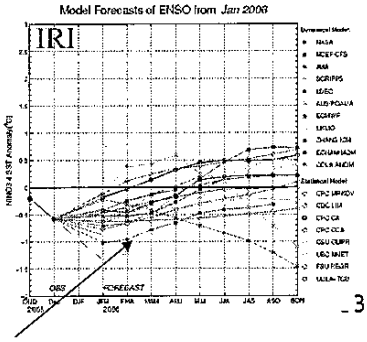
- Monthly CFS forecasts
- Consistent forecast of cold event (-1 K) since June-July 2005
- Other models converging on cold event beginning in January

CFS







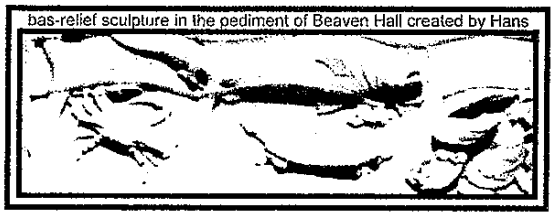


附錄四、Chesapeake Biological Laboratory 相關資料

Ref. No. [UMCES] CBL 07-045

University of Maryland
Center for Environmental Science

Chesapeake Biological Laboratory



CBL is one of three sister laboratories of the University of Maryland Center for Environmental Science.

We pursue our three-fold mission of research, education and public service through our collaborations with the University system, state environmental agencies, the national and international science community and the people of Maryland.

For more information:

Chesapeake Biological Laboratory
P.O. Box 38
Solomons, MD 20688
410-326-4281

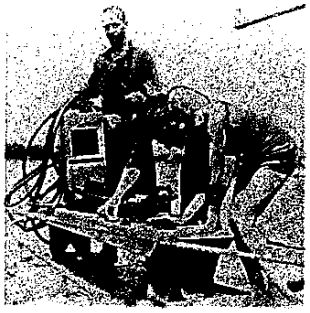
www.cbl.umces.edu

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

Special Series No. SS-100-07 of the University of Maryland Center for Environmental Science.

CBL is the oldest state-supported lab on the East Coast of the United States. It was founded by Dr. Reginal Truitt in 1925 on land donated by the people of Solomons. From the outset, CBL scientists focused on the natural resources of the Chesapeake Bay and developed the scientific data needed to formulate sound management practices. They developed specialized techniques in their quest to study this complex ecosystem and to understand the causes for declining seagrass beds and once abundant oysters and fish populations. Over the years, our successes have contributed to the effective management of the Bay and helped provide a model for effective coastal management programs in other areas.

Today, CBL occupies 16 buildings on over 8 acres of land. More than 125 faculty, students and staff utilize state-of-the-art facilities and a broad range of scientific practices to assess the ecology and health



of the Bay. In pursuing our scientific goals, we combine our search for fundamental knowledge with the development of applications and systems designed to protect the environment and support the wise use of our natural resources.

CBL faculty are currently conducting research in the areas of food web organization, energy budgets of marine ecosystems, the fate and transport of man-made chemicals that enter the Bay from the air and surrounding watersheds, biochemical analyses to determine the effect of sub-lethal stresses on marine animals, and ecological research and management studies on shellfish and finfish.

From its earliest days, CBL has been a center for learning, attracting scientists and teachers from around the country to study at this window on the sea. Our commitment to education is ongoing. We now provide a range of educational experiences for grade school students, as well as undergraduate students from many colleges and universities. Graduate students in residence work directly with our scientists as they pursue their post-graduate degrees. CBL faculty are major contributors to graduate environmental programs in the University System of Maryland.

In carrying out its mission, CBL strives to ensure an informed public by providing convenient access to the results of our research and to the knowledge we have gained about this unique coastal environment.

University of Maryland Center for Environmental Science

Chesapeake Biological Laboratory

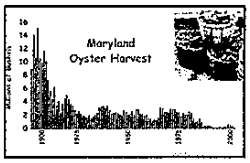
The Chesapeake Biological Laboratory, founded in a small waterman's shack in 1925 by Reginal Truitt, is the oldest state-supported marine laboratory on the East Coast of the United States. It is one of three laboratories of the University of Maryland Center for Environmental Science and home to the University's Research Fleet Operations. CBL has outgrown the original waterman's shack and now occupies 16 buildings on over 8 acres of land at the mouth of the Patuxent River, providing an excellent vantage from which to carry out its three-fold mission of promoting excellence in marine research, educating students of all ages, and sharing the results of ongoing exploration with the larger scientific community and citizens of Maryland.

Research endeavors and graduate educational opportunities at CBL fall into three primary areas; however, as is the nature of environmental and marine sciences, many research projects cross disciplinary lines.

- **Ecosystem Studies** – understanding the processes that link the living and non-living components of a system and the interactions among components in a system
- **Environmental Chemistry & Toxicology** – understanding the sources, transport, transformation, fate and effect of pollutants, natural compounds, and man-made organic chemicals on terrestrial and aquatic ecosystems
- **Fisheries Science** – understanding fished species and the habitats and ecosystems supporting them through an interdisciplinary ecosystem-based research approach

CBL LEADING THE WAY

In the 1950's CBL founder, Dr. Reginald Truitt, was the first Bay scientist to express concerns for the Chesapeake Bay oyster population. He predicted within 50 years without strict management for the oysters there would be a total population collapse.



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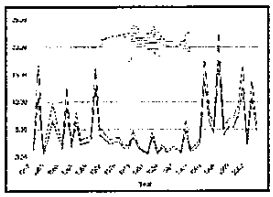
In the 70's & 80's CBL scientists were instrumental in saving a collapsing striped bass fishery. Our research supported the resulting five year moratorium on fishing which ultimately allowed young striped bass to reach spawning age to naturally replenish the population.



Research conducted at CBL has contributed to the critical knowledge base necessary for effective management and restoration of not just Chesapeake Bay but of estuaries and environments around the world. Today, CBL scientists are leading the way in:

- Research efforts to evaluate and manage the Chesapeake blue crab fishery
- Biomarker development for the early detention of pollutant effects
- Ballast water treatment technologies
- Sturgeon restoration efforts along the East Coast of the United States
- Turtle development in response to environmental stressors

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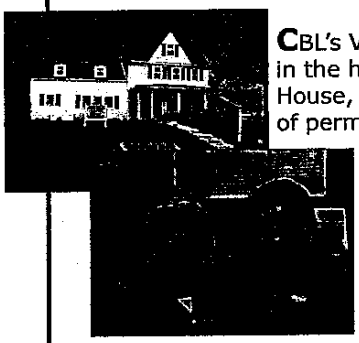
Education - Outreach - Service

In collaboration with Maryland Sea Grant, Maryland Cooperative Extension and the Environmental Science Education Partnership, CBL offers a variety of educational experiences for students and teachers of all ages. Over the past five years, CBL has:

- Offered over 25 professional development seminars, workshops and coures for teachers
- Hosted 10 teacher research fellows
- Hosted 40 undergraduate research fellows
- Provided over 100 lab and field-based experiences for K-12, undergraduate and graduate students



CBL's Visitor Center, located in the historic Solomons House, contains a varied mix of permanent and changing exhibits designed to impart the most up-to-date information about the research efforts undertaken by our scientists. Since it's opening in 1998, CBL has:

- Recruited and trained over 60 docents
- Welcomed over 20,000 visitors
- Published 9 volumes of Solomons Sketches
- Hosted over 65 public seminars and dinner programs

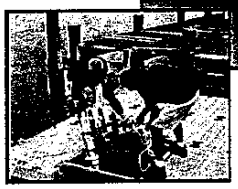
CBL IN THE CLASSROOM

Since 2000, ***300 teachers*** (representing 20 counties):

- Participated in ***283 hours*** of workshops and courses
- Received ***46 continuing education credits***, 14 graduate credits, and 1 advanced certification
- Developed ***42 new classroom lessons***
- Secured funding for ***20 field trips and school projects***
- Made ***14 presentations*** at local and regional meetings
- Developed ***6 new courses, curriculums or professional development workshops*** for their counties
- 65% of teachers reported a ***75% incorporation rate*** of program resources and materials into their classrooms

ALLIANCE FOR COASTAL TECHNOLOGIES

The Alliance for Coastal Technologies (ACT), headquartered at CBL, has been established to support the broad national goals of managing resources for sustainable use, preserving and restoring healthy ecosystems, mitigating natural hazards, and ensuring public health and national security. ACT is a NOAA-funded partnership of research institutions, resource managers and private sector companies working together to provide three unique services:



- **Capacity Building** through technology workshops
- **Testbed** for evaluating the performance of new and existing coastal technologies in the laboratory and under diverse environmental conditions
- **Information Clearinghouse** through a searchable online datatbase of environmental technologies

Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science
Dr. Donald F. Boesch, President

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

MANAGING BAY FISHERIES . . .

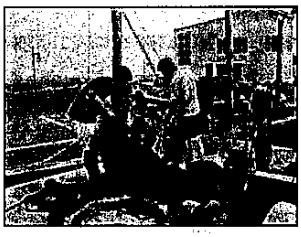
. . . at the Chesapeake Biological Laboratory

DR. THOMAS MILLER

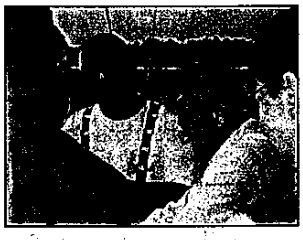
CURRENT RESEARCH OBJECTIVES:

- Determining appropriate reference points for ecosystem based management.
- Assessing how species abundances vary over time and identifying species that respond similarly or oppositely to the same change.
- Determining how the spatial distribution of abundance affect the dynamics of species in an ecosystem.
- Developing tools to track which offspring survive and characterize the traits that made them successful.

SOME CURRENT PROJECTS UNDERWAY:



- **CHESFIMS:** Chesapeake Bay Fishery-Independent Multispecies Survey seeks to quantify trends in abundance and its spatial distribution over time for juvenile stages of fish in the Chesapeake Bay.
- **Mapping Production:** We are seeking to develop techniques that will allow us to map which areas of the coastal ocean are most responsible for the production of juvenile fish. This may promote spatial approaches to management.



- **FishSmart:** Improving how recreational fisheries are managed by directly involving recreational anglers and other stakeholders in the process.
- **Sustainable Fisheries in an Ecosystem-Context:** We are seeking to use a variety of quantitative approaches to mine existing data to understand how estuarine and coastal ecosystems should be managed for sustainable fisheries.

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T. Miller & J. Takacs

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Maryland Sea Grant
Gordon and Betty Moore Foundation

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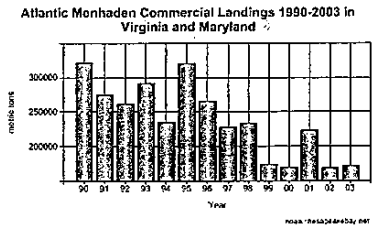
MANAGING BAY FISHERIES . . .

. . . moving beyond 1 Fish, 2 Fish, Red Fish, Blue Fish

ONCE GREAT FISHERIES?

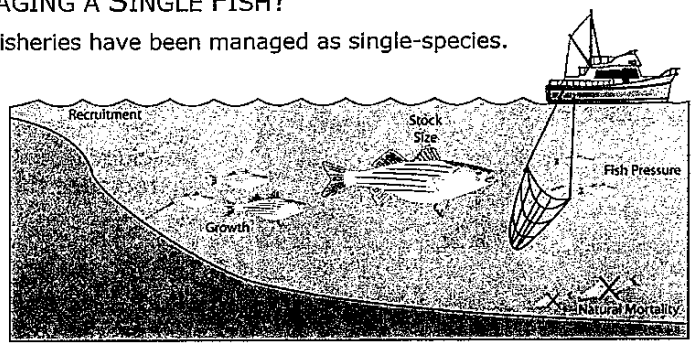


Chesapeake Bay has seen dramatic declines in many of the fish and shellfish stocks that once supported rich commercial fisheries. Oyster stocks are at a few percent of their historical abundances. Shads once supported a substantial fishery in the rivers that feed the Bay – but such fisheries are now closed. Striped bass, which is now abundant, was only recently subject to a moratorium.

MANAGING A SINGLE FISH?

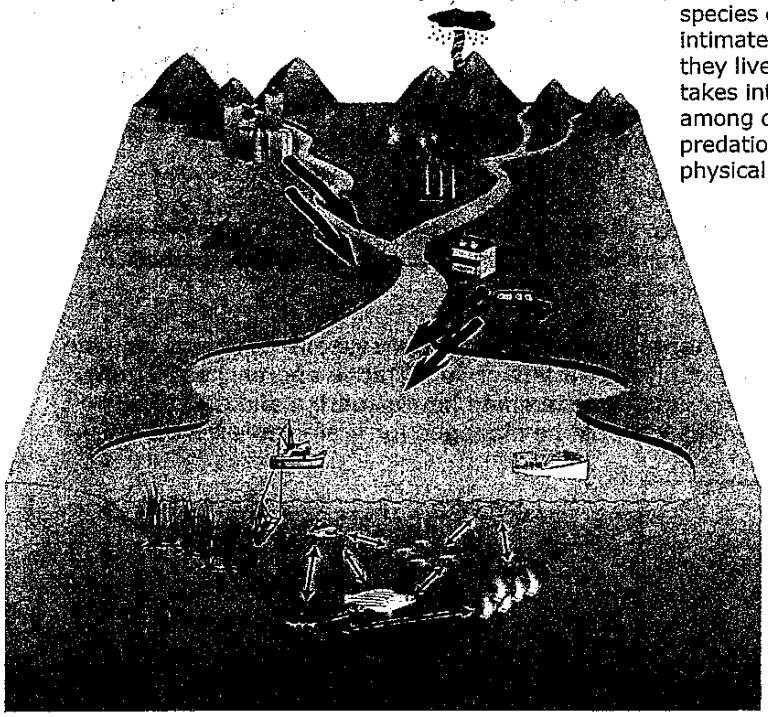
Traditionally, Chesapeake Bay fisheries have been managed as single-species.

A single species approach to management treats the managed species in relative isolation – balancing catches against its reproduction. It assumes that new individuals, over and above those needed to replace fish that die, can be caught – that is such surplus production has no role in the ecosystem.



THEY AREN'T OUT THERE ALONE!

Ecosystem-based fisheries management (EBFM) is an approach that recognized that individual fish species do not exist in isolation, but are intimately linked to the environment in which they live. This new approach to management takes into account the relationships that exist among different species (competition and predation) as well as between species and their physical, chemical and biological environments.



EBFM seeks to balance the catches against the reproduction **and** the "services" that each species provides to the ecosystem. Services might include:

- Food for predators
- Cleaning the water column
- Recreational opportunities
- Aesthetics

As a result EBFM must include more points of view when allocating catches.

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OCEAN ACIDIFICATION . . .

. . . how carbon dioxide in the atmosphere makes seawater go sour!

WHAT IS IT & WHERE DOES IT COME FROM?

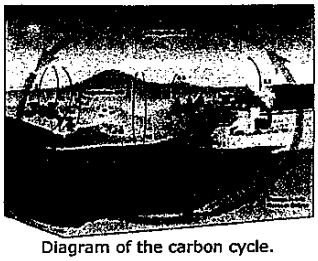


Diagram of the carbon cycle.

CARBON DIOXIDE – CO_2

- It is a colorless, odorless, non-poisonous gas that makes up about 0.03 percent of the atmosphere.
- It is naturally produced through respiration, decay, ocean processes and volcanic eruptions.
- It is a vital component in maintaining a balanced global carbon cycle between the atmosphere, the land and the oceans.

TOO MUCH OF A GOOD THING?

Humans are artificially increasing the amount of CO_2 in the atmosphere through the following:

- Burning of fossil fuels (natural gas, oil & coal) 
- Production of cement 

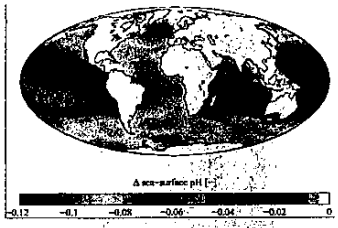
These artificial increases can not be handled by our natural carbon cycle and as such have led to some potentially serious environmental impacts.

1. Global Warming – excess CO_2 contributes to an increase in greenhouse gases resulting in global warming (CO_2 traps heat in the atmosphere warming the earth). Global warming has been associated with sea level rise, habitat loss and other environmental issues.

2. Ocean Acidification - a decrease of ocean pH due to the formation of carbonic acid as a result of increased dissolved CO_2 concentrations.

$$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3^-$$

Carbon dioxide + Water = Carbonic Acid = Hydrogen + Bicarbonate



Change in sea surface pH caused by man-made CO_2 between the 1700s and the 1990s

SOUR OCEAN?

EFFECTS OF OCEAN ACIDIFICATION

- Many organisms in the oceans make their shells and other parts out of calcium carbonate – taking the ingredients they need directly from the ocean.
- When ocean pH drops the chemical composition of seawater changes making some of the needed ingredients no longer available for use.
- Organisms that can not make their shells die.

WHO ARE THESE ORGANISMS? WHY SHOULD WE CARE?

- Many of the affected organisms are microscopically small and probably unknown to most of us but they play important roles in the aquatic food web.
- Others – like coral and oysters – are more recognizable and support commercial industries as well as being a vital link in the aquatic environment.

How much CO2 are you responsible for? Determine your carbon footprint at: http://www.climateprotect.org/aa17

WHAT CAN YOU DO TO REDUCE YOUR CARBON OUTPUT?

- Use energy efficient appliances
- Recycle
- Carpool
- Turn off lights
- Reduce water usage

For more information about reducing your carbon footprint, go to: http://www.climateprotect.org/aa17

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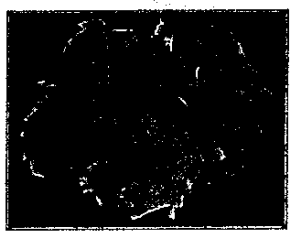
CHESAPEAKE BIOLOGICAL LABORATORY

METALS . . .

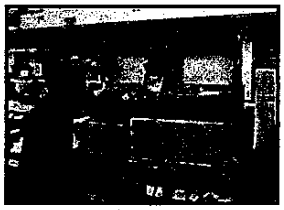
. . . at the Chesapeake Biological Laboratory

DR. JOHAN SCHIJF

CURRENT RESEARCH OBJECTIVES:

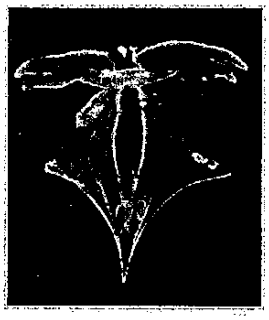


- Understanding how metals are taken up or released by simple marine plants, like seaweeds.
- Modeling how metals in seawater interact with mineral particles under different environmental conditions.

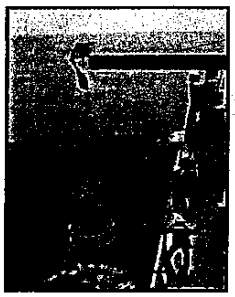


- Explaining the chemical behavior of metals in marine 'dead zones' and other places where oxygen is depleted in the water column.
- Determining how metals are transported by rivers and groundwater, from the land to the ocean.
- Developing new analytical techniques to measure extremely low metal concentrations in natural water samples.

SOME CURRENT PROJECTS UNDERWAY:



- Why does sea lettuce accumulate high levels of metals and can we use this knowledge to monitor metal pollution in coastal waters?
- Is atmospheric carbon dioxide pollution making the oceans more acidic and will this prevent tiny swimming snails from building their shells?
- Are bacteria producing methyl-mercury in a layer of very salty water 2250 meters below the surface of the Gulf of Mexico?



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